Susan Rowland · Louise Kuchel *Editors*

Teaching Science Students to Communicate: A Practical Guide

Springer

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An Introduction to Science Students and Communication in the Workplace

1

Louise Kuchel and Susan Rowland

Abstract

A science degree *can* lead to a career in science but, for the majority of science graduates, their pathway lies elsewhere. Although we do not know exactly where our graduates will work, we do know communication plays an important role in the work and personal lives of graduates. In this chapter, we will discuss where science graduates are employed, how communication capabilities contribute to employability, and what meaningful teaching of communication in science programs looks like. We aim to set the scene for the rest of this book so you, as an educator, can understand the importance of helping science students learn to communicate, and we provide you with an overview of how to use this book in your teaching.

1.1 Why Do Science Graduates Need to Learn to Communicate?

A science degree *can* lead to a career in science but, for the majority of science graduates, their pathway lies elsewhere (OCS report, 2020). As we educate science students, it is important for us to remember this. We are educating future scientists, but we are also educating many people who will never work in a lab or conduct a

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research study (McInnes et al. 2000; Leuze 2011; Logan et al. 2016; Palmer et al. 2018).

Although we do not know exactly where our graduates will work, we do know something about their futures. They will seek employment, and during this process, they will need to articulate who they are, what they can offer, and why their scientific training is valuable. They will also enter society as science-informed citizens and ambassadors for the scientific way of approaching decisions and debate (Harris 2012). To achieve these things, our graduates need to know how to communicate.

In this chapter, we will discuss where science graduates are employed, how communication capabilities contribute to employability, and what meaningful teaching of communication in science programs looks like. We aim to set the scene for the rest of this book so you, as an educator, can understand the importance of helping science students learn to communicate.

1.2 Where Are Science Graduates Employed?

Often as academic educators, we fall into the trap of thinking we are primarily educating more of ”us”—more scientific researchers and academics. While scientific research and academia are both important and fulfilling careers, they do not constitute the limits of gainful science employment. The Science Council (2021) provides valuable resources that define both science and scientists. They also discuss the multiple different types of scientists our graduates can become—business, developer, entrepreneur, explorer, investigator, policy, regulator, teacher, technician, and communicator—and provide a self-test that students can take to get a sense of where they would like to go in science.

These options assume that science graduates are working in science, but our science graduates also have a lot of other career options. Recent Australian studies show that more than 50% of science graduates do not work in science (Leigh et al. 2020). The non-science career destinations for science graduates are extraordinarily diverse. They include management, finance, marketing, health, education, IT, professional work, and construction (Palmer et al. 2018). Some of these careers eventuate because graduates cannot find work in their area of disciplinary expertise, but many others are deliberately chosen by graduates.

Indeed, many of our students enter their science training with the goal of working beyond science once they complete their education. A large study in the UK found that only around half of STEM graduates “definitely” wanted a career in their study area (Mellors-Bourne et al. 2011). Students who complete a research degree are also not wedded to the idea of continuing in science. Studies of science PhD students in the US suggest that at least 50% are interested in non-academic careers (Fuhrmann et al. 2011; Roach and Sauermann 2017), and of these only a tiny minority of PhD graduates (between 2 and 5%) actually end up obtaining a stable academic position (Rowland 2016).

This information about science graduate outcomes reminds us that science graduates will need to make choices about their work options and compete for employment (Boden and Nedeva 2010; Office for National Statistics 2012a; Siefert 2011). The modern work landscape is complex and changeable; not surprisingly, universities are under pressure to develop graduates who can navigate this landscape successfully. In this context, graduate employability has become a significant focus in a number of western countries and higher education institutions, and communication abilities are a key contributor to employability.

1.3 Communication As an Employability Literacy

Employability can be conceptualised in several ways, but perhaps the best-accepted definition comes from Mantz Yorke (2006). He describes employability as "a set of achievements—skills, understandings and personal attributes—that make graduates more likely to gain employment and be successful in their chosen occupations, which benefits themselves, the workforce, the community and the economy" (Yorke 2006, p. 7). Clearly, the ability to communicate would fall under this umbrella. Dawn Bennett also describes a set of Literacies for Life that prepare students to thrive in the workplace. Bennett (2017) classes "communicating and interacting with other people" as a Basic Literacy.

When we contemplate teaching our students to communicate, we should keep this idea in mind—communication is not just about transferring science content from one person or organisation to another. Communication is also about making connections, interacting for mutual benefit, and problem solving. Communication is about asking for input, valuing the ideas of others, and making informed decisions.

Teaching students to communicate is not easy. It can be difficult for students to understand the relevance of communication-related learnings to their curriculum and their goals. It can also be difficult for science educators to teach communication in a way that they think is discipline-appropriate. In response, we and others have addressed communication teaching and learning using the lenses of work and study (Rowland et al. 2018 (www.clips.edu.au); Bennett 2017, (employability toolkit and educator website). This employment and assessment-linked approach is something that students appreciate and can use as a driver for improving their practice. This idea—that teaching communication should be linked to students' real-world needs—is the genesis for this book.

1.4 Teaching Meaningful Communication in Science Programs

We are all, as academic educators in science, familiar with teaching and assessing traditional forms of science communication—written scientific reports, conference-style presentations and project proposals (Stevens et al. 2019). We value these genres because they are authentic ways for students to learn and demonstrate their understanding of many aspects of scientific inquiry. But in the context of modern scientific practices and in developing students' employability, they are severely limited.

Consider all the reasons why science-trained graduates need to communicate—to solve problems, to suggest solutions, to negotiate, to ask for input, to be part of the conversation, to collaborate, to share data, to shape policy, to discuss their ideas. The list is almost endless. The lab report, the poster, the risk assessment, and the conference-style presentation are not enough for these graduates.

Meaningful teaching of communication focuses on foundational ideas in communication and a variety of core skills and practices that will serve students beyond university. We can think of teaching communication in a science degree as analogous to the challenge of teaching science in a journalism degree. Journalism academics will not prepare their students to be specialist scientists, and in science we are not aiming to develop professional communicators. We are, however, working to provide a foundation from which students can become agile and extend.

For example, developing habits of mind where we ask "who?" "what?" "when?" "how?" (Wack et al. 2021; Bean 2011) and practising the principles of the rhetorical triangle are among important foundations for meaningful teaching of communication. Core communication skills such as taking notes, working in teams, and active listening are also meaningful learnings that students benefit from in the short term and can build upon beyond university. Ways to teach all of these practices are addressed in this book.

Meaningful teaching of communication does not detract from learning science—it improves it. Quality educational practices often involve foundational communication ideas and practices. For example, articulating our knowledge and thoughts in different ways to different audiences sharpens and clarifies our thinking. Asking students to do this helps instructors identify learning trouble-spots. The acts of writing and speaking improve our working memory's ability to connect new information to past knowledge and experiences. Asking students to speak and write helps their working memory process information. Critical thinking and argumentation skills improve as we review and reorganise our thoughts to build a presentation (e.g., Bean 2011); asking students to present material helps them learn to be discerning and organised consumers and conveyors of information. We also know that engaging students in active discussion and interpersonal interaction is more effective than traditional, passive teaching modes in helping students learn science (Wieman 2014).

Teaching foundational communication ideas and skills need not be time-consuming nor difficult. It can be incorporated into existing teaching by academic science educators to enhance student learning. This book brings practical communication-learning tools to science educators so we can all get started!

1.5 Using This Book in Your Teaching

This book was born from our collective experience working with our teaching and research faculty colleagues, with employers of science graduates, and with science students who struggled to communicate. The section titles for practice chapters reflect common, desirable attributes we hear discussed by employers and see described in job advertisements for science graduates. The teaching activities outlined are exciting and practical ways in which these attributes can be taught in the science curriculum.

We recognise that academic science educators often feel ill equipped to teach communication. Many of us have learned our communication practice tacitly or during a research apprenticeship. Many of us are also faced with a crowded curriculum in which content is king! In some cases, our students also struggle to understand why learning to communicate is important. In response, this book provides enough detail to give educators a grounding in communication, and in the pedagogy needed to teach it in a way that relates to the science curriculum. Importantly the book is *not* a manual to help people teach the discipline of science communication. It is focused, instead, on helping scientists teach their science students to communicate.

The chapters are built to help unpack the practice and pedagogy of communication learning. The theory chapters explain key concepts in communication to give instructors some background as they teach communication in their class. These chapters will be useful when students ask why communication learning is relevant to their futures.

The practice chapters offer classroom-ready activities to teach important aspects of communication; each chapter explicitly articulates what communication skills and concepts students learn and explains how to teach the class. The activities offer high-value learning, but they are also pragmatically short (taking between 15 min and 3 h to implement)! The practice chapters include a run sheet for the class, questions to facilitate discussions, and links to useful resources. All practice chapters use active approaches to teaching, with tips and tricks provided by the author to support instructors unfamiliar with this style of teaching.

As such, this book offers a plug-and-play approach to incorporating communication in science programs. The activities have been tried and tested with science students by the authors, most of whom are academic science educators. The activities can enrich existing communication pedagogies or introduce a new approach where such pedagogies are absent. Importantly, the activities are transportable and complementary. Instructors can adopt one or many activities in an individual class, in a unit of study, or across entire programs.

In this book, we recognise communication as something more than presenting a written or spoken piece. Drawing from how communication is taught in language studies (e.g., American Council for Teaching of Foreign Languages; Sandrock et al. 2012), we recognise that foundational communication skills involve listening, reading, interpreting and interpersonal interactions, and that in science, communication involves working with numbers and code as well as with words.

Learning to communicate can help students identify their interests and strengths and inspire them to move into areas that are challenging and unknown. Learning to communicate can also help science graduates help others and spread the gifts of science to society.

We are deeply grateful to the educators and science communicators who have authored chapters and shared their practice through this book. Thank you for your

wisdom and your collegiality! We hope that this book is the beginning of a larger movement of sharing practical teaching of broad communication skills to enhance both teaching and learning of science and student employability.

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Part I

Theory Chapters

Rhetoric, Influence, and Persuasion

2

Louise Kuchel and Susan Rowland

Abstract

The art and practice of rhetoric is crucial to human communication. Rhetoric allows people to compel attention, to convey information, and to influence and persuade one another. Applied in different ways it can invite or hinder meaningful conversation, enhance or obscure academic argument, and help resolve intellectual problems. In this chapter, we explain rhetoric, Aristotle's rhetorical triangle, and the rhetorical situation. We also discuss how these shorthand guides (heuristics) for composing an argument can improve the teaching of communication in science.

2.1 Aristotle's Influence

> "Rhetoric may be defined as the faculty of observing in any given case the available means of persuasion."—Aristotle (Kennedy 2007)

Although we may not know it by its formal name, rhetoric is something we are all very familiar with. It is the art of persuasion and influence and can be used to understand things from another person's perspective (Burke 1969; Roskelly 2008). It is all around us in advertisements, movies, art, social media, body language,

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everyday conversations, and scientific arguments. Done well, the art and practice of rhetoric leads to a meaningful, two-way dialogue.

Each of us employs the tools of rhetoric daily, but we are usually unconscious of our rhetorical practice. By becoming aware of how rhetoric works we become more discerning of what we see, hear and read. We also become more able to identify how we are persuaded and decide whether arguments are sound and sources are credible. An understanding of rhetoric makes us more effective communicators. This capability is valuable for any science graduate.

Rhetoric was first established as a formal theory by the ancient Greek philosopher Aristotle in the fourth century BC, and it remains central to our practice of persuasion today. His theory arose in the context of dramatic cultural change that brought about the political and legal reform of democracy. As you might imagine, understanding how to influence a broad range of audiences and see issues from different perspectives was key to this shift.

At a time when most people could not read or write, broadcast communication took place mostly through public speaking. Aristotle believed that speakers could observe how best to communicate by considering the interactions between three key elements in what we now know as the rhetorical situation: the speaker, the audience, and the subject (Fig. 2.1). He argued that by using this understanding, orators could develop sound and convincing arguments. To improve the persuasiveness of these arguments, Aristotle and his philosophical descendants identified the three rhetorical appeals: logos (logic), pathos (emotion), and ethos (credibility). Thus, Aristotle's rhetorical triangle (Fig. 2.3) forms an underlying framework for all communication (Roskelly 2008). We discuss the specifics of the rhetorical situation and rhetorical triangle in later sections of this chapter.

By actively considering rhetoric when we conduct and teach science we can improve the rigor of our work and the effectiveness of our communication. For example, we can use rhetorical analysis as a powerful way to examine the rigor of a scientific argument, theory, or debate. It is helpful here to know that when discussing rhetoric, the term argument refers to the content or subject matter of what is being discussed (e.g., Darwin's theory of natural selection), and the term rhetoric refers to

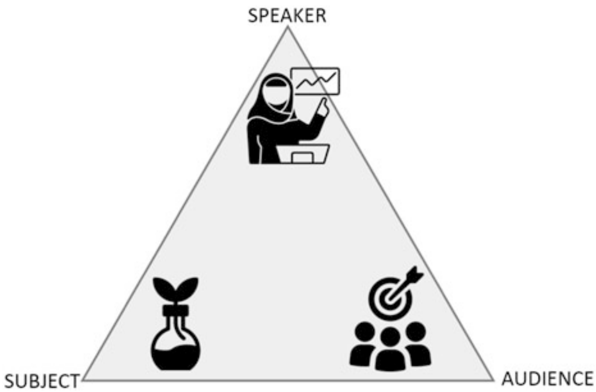

Fig. 2.1 The basics of Aristotle's rhetorical situation: the speaker, the audience, and the subject

"how" that subject matter is conveyed irrespective of the subject matter. So, if we conduct a rhetorical analysis on an argument, we can identify what factors or strategies are being used to persuade the reader or listener about the ideas being discussed. Although scientists strive to be objective by using an evidence-based approach to our work, we are also human and are influenced by the cultural norms, insights, and interpretations of the day. Conducting a rhetorical analysis helps us look objectively at the argument (Longaker and Walker 2011), and reduces the possibility that we will be swayed by pathos or the apparent ethos of the speaker.

Rhetoric is a powerful tool for facilitating an open, two-way exchange of ideas, but it can also be used to confuse and mislead an audience. Rhetorical fallacies are powerful distraction tools that derail the audience's logic process (Lunsford and Ruszkiewicz 2004). For example, emotional fallacies play unfairly on emotional appeals, such as those we see in anti-vaccination campaigns that prey on parent's fear of permanent, severe, vaccine-induced damage to their child, despite overwhelming evidence of vaccine safety. Similarly, ethical fallacies overplay the authority, credibility, or character of the messenger. We can see this in advertisements for cosmetics that use imagery and terminology from science to lend credibility to their (sometimes unproven) claims. Logical fallacies depend on faulty logic; a detective game adults love to play with young children.

The ability to identify rhetorical fallacies helps us understand where and how an argument may be incomplete or twisted (Tindale 2007). This, in turn, helps us explain science to an audience that has been misinformed or misdirected. Through being conscious of rhetoric and by calling out rhetorical fallacies, we are better able to facilitate meaningful and constructive conversations, which of course depend upon an open exchange of ideas.

Adapting the way we talk or write about science to a variety of audiences and purposes is far more effective when rhetoric is considered and rhetorical tools are applied, as we will explore below. Although there is more to the art of persuasion and influence than rhetoric, rhetoric provides an excellent foundation.

2.2 The Rhetorical Situation

To observe how best to communicate, Aristotle considered the situation in which communication takes place, and the interaction between its three elements: the *audience*, the *subject*, and the *speaker* (Rapp 2010). When we think about an orator in ancient Greece, the notion of Aristotle's speaker addressing a crowd of spectators or listeners makes sense. In modern rhetoric 'audience' refers more broadly to any person or group of people receiving communication (e.g., a listener, a reader, a viewer, or a participant in a conversation), and 'speaker' is the person communicating the message (e.g., a writer, speaker, an organization, or visual artist).

Subsequent scholars have elaborated on Aristotle's rhetorical situation by acknowledging that the *context* in which communication takes place and the *conventions* used to communicate in that situation (known as *genre*) also inform best practices in communication (Rapp 2010). These scholars suggest that Aristotle

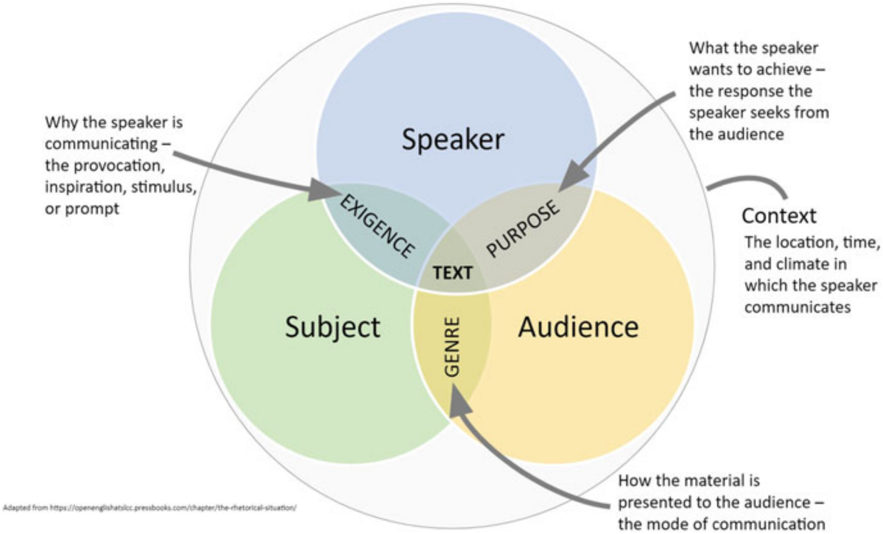

Fig. 2.2 A modern schematic of the rhetorical situation, which expands on Aristotle's three basic elements. Adapted from https://openenglishatslcc.pressbooks.com/chapter/the-rhetorical-situation/

operated in the narrow context of ancient Greece's elite society, so he likely assumed a set context and genre in his model. Other scholars have elaborated even further and modernized some of Aristotle's associated ideas (Fig. 2.2, Rapp 2010); they explain that we should also consider the *purpose* of the communication, *exigence* (the issue, problem, or situation that causes someone to communicate) and *text* (or words in the case of spoken communication). By observing how each element interacts with the others we can fine-tune how to communicate most effectively.

The rhetorical situation is used widely in teaching communication (especially writing in, for example, the Writing Across the Curriculum (WAC) and Writing In the Disciplines (WID) pedagogies; https://wac.colostate.edu/resources/wac/intro). Many of the practice chapters in this book draw explicitly on elements of rhetorical situation theory in their pedagogical design.

2.3 The Rhetorical Triangle (Appeals)

To successfully influence or persuade in a given situation, we need to consider the three appeals that make up the rhetorical triangle; *logos*, *pathos*, and *ethos* (Fig. 2.3). In order to be convincing, we typically use all three appeals but emphasize one more than others depending on our audience, the topic, and our communication goals. Let us take a closer look at each of the appeals.

We begin in the comfort zone for most scientists (and most science student communicators), logos. Logos is the appeal to logic. By conveying a point of view that appeals to the rational thinking and reason of our audience, we are using logos.

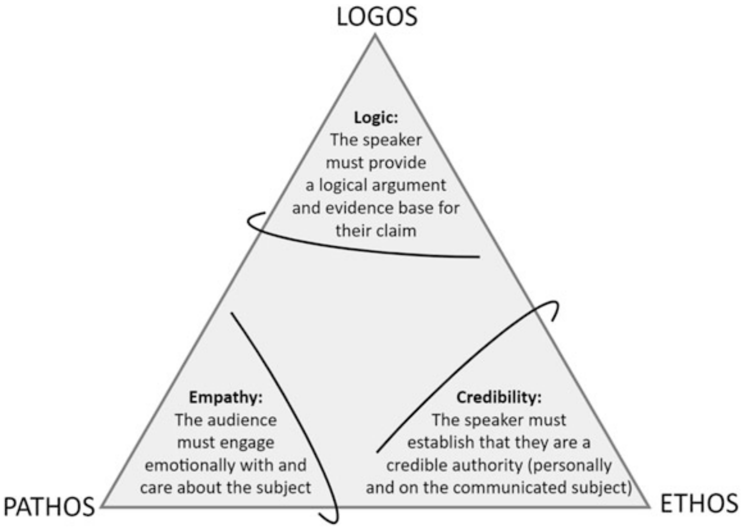

Fig. 2.3 The rhetorical triangle depicting the three appeals: logos, pathos, and ethos

This approach aims for the head, not the heart. We typically apply logos through reasoned discourse and logical argument supported by evidence. So, logos not only includes examples, facts, figures, and statistics as forms of evidence, but also the overall message and structure of the communication, where a claim is supported by evidence.

Aristotle considered logos to be the most powerful of appeals. It is a staple of academia and the legal system, but it has its limits. Although logos is crucial for communicating science, a logos-only communication event is unlikely to win over an audience. This is because humans are not entirely rational. The anatomy and wiring of our brain dictates that our amygdala, the home of our flight and fight responses, is the first to respond in any rhetorical situation. This means we can use emotions to connect our audience to our subject, and we should pay attention to pathos when we communicate.

Pathos is the appeal to emotion—it aims for the heart, not the head. Emotions are universal, and ancient or core emotions (like fight and flight responses) are relatively easy to elicit. In contrast, rational thought (the logos target) requires significant cognitive work that occurs in the outer cortex of our brain and takes longer to process. The emotional disposition of an audience is important; humans do not interpret and judge communication in the same way when we are angry or happy, annoyed or relaxed. For this reason, it is important to influence an audience's emotions. Because of its universality, pathos is commonly used when the aim is to reach a large number of diverse people (such as in advertising or advocating for a cause).

A communicator tapping into pathos wants the audience to feel something—anger, fear, happiness, joy, pride. Emotions make us feel vulnerable, and pathos can be used to “open up” an audience and help them be more receptive to a communicator’s argument. A short-term appeal to the emotions also helps people activate memory formation by association with previous emotional experiences—as a result emotional (or pathos-associated) information is better remembered than neutral information (Tyng et al. 2017 and references therein). Pathos can be communicated in a multitude of ways, such as through imagery, tone, expressive descriptions, personal stories, and more. Too much pathos, however, can be counterproductive. Heavy-handed use of emotional appeals makes an audience feel manipulated, skeptical, or even cynical, which will reduce their attention to the message.

When using pathos, and logos, a speaker should also convey a sense of ‘authority to speak’ (or ethos) around their communication topic. If they do not, the audience is unlikely to engage with or believe them. Ethos broadly refers to the credibility and authority of the source of information and/or the communicator, be it an organization, or person. What is considered credible by some people may not be considered credible by others. This credibility gap (or credibility question) is a big challenge in modern communication as societies become larger and more fragmented, and as social media provides us with a vast diversity of speakers. Who and what audiences consider to be credible often relates to their values and beliefs as much as it does to the reputation and authority of a communicator.

Even expert scientists can have difficulty establishing credibility with an audience (especially in this modern age of science denial), but there are multiple ways to go about it. Methods build credibility include establishing common ground with an audience, referencing past achievements, citing affiliations with research bodies, referring to the work of others to contextualize one’s own work, explaining personal experiences with the subject, endorsement by well-known public figures, association with reputed organizations, depth of knowledge about a topic, appearance (or “looking the part”), and use of body language. Some of these approaches benefit from the use of pathos as well (for example, a cancer survivor will have ethos and pathos appeals when they talk about the revolutionary treatment that saved their life).

When applied together and in a heuristically tailored mix, ethos, logos, and pathos produce a powerful communication event.

2.4 Linking Rhetoric to Your Science Teaching

In our experience, giving science students even a small amount of training in the elements of rhetoric pays big dividends.

Showing students the rhetorical triangle, for example, helps them understand that they can move beyond dry logos-focused communication, and can inject pathos into their practice. This is exciting for them—usually they *are* passionate about science, but they try to adopt a non-emotional approach to it because they feel a logic-only demeanor is “sciency” behavior! Give them permission and encouragement to engage the emotions of their audience and watch them come alive as communicators.

Ethos can also be difficult for student presenters to establish; students often feel illegitimate as keepers or communicators of knowledge. Establishing expertise, or learning to inhabit the role of expert, takes time and self-confidence. It is important that, as educators, we encourage our students to build their capabilities around projecting ethos and explain that while there may be one 'formal' educator in the room (the instructor) we all learn and teach all the time. Again, giving students explicit permission to project ethos is valuable and exciting, and will improve their communication practice.

Logos relies as much upon structure and composition as it does on evidence. While science students often have a natural tendency to focus on logos, because it sounds sciency, many will not have dissected it to know how to build a logical argument. Focussing explicitly on logos allows us to talk with students about evidence-based reason. We can encourage them to consider the various types of evidence available (e.g., examples, data, qualitative, quantitative, etc.) and the claims (or key messages) they wish to make about each bit of evidence. They can also address their argument the other way—starting with the claims and looking for evidence to support them.

To create logical flow, students can ask questions like: What knowledge does my audience already have on this topic? What do they need to know? What new things do I want to convey (the claim/s)? How will I help my audience believe the claim (the logically-linked evidence)? Have I provided reason that connects the old information to the new information I have added?

By breaking down their argument into steps, students can identify the familiar and new information at each stage of the argument and use it to create links between the ideas. Following this pattern helps to identify gaps in logic as well as improve the flow of ideas. Asking students to explain their reasoning to each other can help them clarify their ideas and logic.

Several chapters in this book demonstrate directly how to use rhetorical tools or thinking in teaching communication to science students (e.g., Chapters 20, 38, 60), but here are three simple pedagogical suggestions to get you started:

1. *Provide a rhetorical situation for communication:* In each communication task, you set for students, provide an explicit, specific, targeted rhetorical situation for students to focus on. The more specific and authentic the rhetorical situation, the more tangible the task is for students, and the easier it is for them to make decisions about how best to communicate. Including a specific rhetorical situation also makes for clearer task guidance and easier marking decisions. Advocates of this approach usually recommend specifying audience, purpose, genre, and a reminder for students to reflect on trouble spots in their writing. Two example methodologies are RAFT (Role, Audience, Format, Task; Bean 2011) and PACT (Purpose, Audience, Conventions, Trouble/Translation/Technique; Speakwrite 2011; Bunn 2011).

   Providing a rhetorical situation also opens opportunities to embed authentic situations into course tasks by linking them with workplace scenarios. Some examples of specific rhetorical situations related to the workplace include: a pitch for your idea to your workplace supervisor; explaining the benefits of a new diagnostic kit to a potential buyer; presenting a negative environmental impact statement to a government department; explaining the science of vaccines to a skeptical family member.

2. *Conduct rhetorical analysis of opinion articles or scientific papers:* In science education, we frequently ask students to distill the essential message of an article or talk ('What is this paper about?'; 'What are the key findings?'). We rarely, however, go further and ask for a rhetorical analysis of the piece. In a rhetorical analysis, we examine how a text, talk, or other communication event persuades us of the speaker's point of view. We can ask: How does the speaker connect to the audience and frame the issue? How do they establish the issue's importance? How do they make and support a claim about the issue? What tools do they use to persuade their audience to accept the claim? Are you, the reader, convinced by the argument and why? This kind of analysis asks students to understand the craft of the communicator, which will likely also help them better understand the content being communicated. For an example task description see Willihnganz (2008).
3. *Make a rhetorical plan for a spoken or written assignment:* This activity requires students to take a stance on an issue, which could range from something simple (e.g., the results of their gel electrophoresis), to something massively complex (e.g., the role of permafrost bacteria in global warming). When students make a rhetorical plan they can use the rhetorical situation diagram and the rhetorical triangle to consider the interlocking aspects of their communication practice. Working through the diagram with a partner is an ideal way to help students get a better grasp of what, why, and how they are communicating. Rhetorical plan production is ideal for helping students construct compelling introductions and discussions in scientific reports. It also, of course, is useful for constructing communication events with political and/or public audiences.

2.5 Conclusion

The art and practice of rhetoric is familiar and intuitive to all of us, from the conversations we have with friends and family, to advertising, and scientific writing. By bringing rhetoric into our consciousness and developing habits of mind around it, we can all improve and sharpen our communication work. An awareness of rhetorical theory and practice enhances our critical thinking capability and is highly valuable both in practising science and in communicating successfully in the workplace. As educators, we can use the rhetorical triangle and rhetorical situation diagrams as powerful tools to help students improve their communication practice.

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3 Good Science Communication Considers the Audience

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Abstract

While those who teach science at university are accustomed to thinking about communication with other scientists, less attention is generally paid to public science communication. Yet it is imperative that scientists are equipped to communicate with diverse audiences. An essential step of planning any communication involves considering the audience. How might an audience engage with and respond to the communication? This can make the difference between communication that is impactful or ineffective. This chapter provides a brief overview to help:

- Identify audience types.
- Consider the most appropriate mode of communication for engaging with particular audiences.
- Consider factors that influence individual reception and use of information.
- Reflect on the appropriate audience level for different communication objectives.
- Appraise the importance of culture and different world views.
- Increase equity and inclusivity.

The chapter concludes with a checklist about audience factors to consider when developing a communication activity or resource.

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3.1 The Importance of Audience

An early step in planning any communication should be to consider how the intended audience might engage with that communication and respond. It is important to remember that one potential and common response to any communication is to ignore it. That is not surprising, given the sheer volume of communication we are faced with each day. Choosing what communication to ignore, engage with, or respond to is part of the human condition. This chapter elaborates on factors that affect audience response. Consideration of audience improves the probability that communication will impact and engage the audience rather than being ignored or relegated to the back burner.

When teaching university science students about communication, the audience that students are tasked to communicate with is often not considered or is implicitly expected to be fellow scientists (Stevens et al. 2019). Explicit designation of the target audience for a written or spoken task can embed consideration of the audience as a valuable part of the learning process. The checklist of audience considerations at the end of this chapter is a useful starter for this purpose. Another useful scaffolding step in a communication assignment is to ask students to consider different potential audiences. Advanced students can be tasked with deciding on their audience, justifying their decision, and tailoring their communication appropriately.

This chapter focuses primarily on communicating with audiences other than scientists, although the principles apply to all audiences of science communication.

3.2 Three Types of Public Audiences

There is no universal "audience," in the same way that there is no single "general public." The appropriate audience, achievable objective, and best way to communicate will vary with the topic, public awareness and knowledge about it, and the objective of the communication. Here, I describe three types of audiences, consider factors affecting communication approach, and illustrate how the most appropriate mode of communication is likely to be different for each.

Each type of audience is composed of individuals whose perceived identity impacts their engagement with information (Longnecker 2016). Identity can be related to demographic factors such as age, ethnicity, and socio-economic factors. More important factors in identity are values, beliefs, awareness, and understanding. Any individual will also experience conditions such as culture, social norms, personal control, and external support that may influence their response to any communication effort.

3.3 Interested, Appreciative Audience

This type of audience is one that will be familiar to scientists who have given conference talks, written scientific papers targeted at other scientists, or taught students who have chosen to study a science course. This type of audience is also commonly targeted for public science communication. For example, prospective student and science outreach activities often target audiences who have already indicated interest and aptitude in science.

Perhaps one of the easiest, most satisfying, and hence most common activities in science communication with nonspecialists is a traditional public talk, where an expert shares information about their own work with an interested, self-selected, and appreciative audience. This type of one-way public communication falls into a category often called the "deficit model" of science communication (Simis et al. 2016). It is a valid science communication activity in the right circumstances; it can be deeply satisfying to both a curious audience and to an expert whose hard work is appreciated. It may also be a valuable way to practice one's message and style of communication.

For public science communication to be inclusive and wide-reaching, communication efforts should not end with this type of audience. Nor should the deficit model be the default approach to science communication, although it is useful in some circumstances.

3.4 Uninterested Audience

Science communicators may want an audience to engage with something that is of no apparent interest to them. The audience may perceive the subject to have little relevance to their lives (Dawson 2018). This requires the science communicator to consider why they want to communicate with this audience and consider the audience's circumstances and motivations. What might motivate the audience whom you would like to engage? Is the information relevant to them? What are the identities of your potential audience(s)? Consider your audience's relevant values, beliefs, attitudes, awareness, emotional status, level of understanding, skills, and behaviors as discussed below in the section, *Focus on the Individual*. These internal factors affect whether and how an individual will engage with new information (Longnecker 2016).

3.5 Skeptical or Polarized Audience

The biggest challenge in science communication is trying to persuade a skeptical audience to change their attitudes or behavior. You may consider your communication to be useful and important. But will your communication resonate or rankle? Is your intention to persuade or provoke? Factual communication about climate change or vaccination may appear clear-cut but response to information can be different for audiences with different perspectives (Kahan et al. 2010; Manyweathers et al. 2017). Thinking about barriers or perceived barriers that need to be overcome and listening to potentially valid concerns that may not have been considered by experts are important in determining a way forward (Manyweathers et al. 2020; Wynne 1989).

Successful communication aligns with the audience's key values (see Fig. 3.1). This is particularly challenging with mixed audiences where there will likely be a

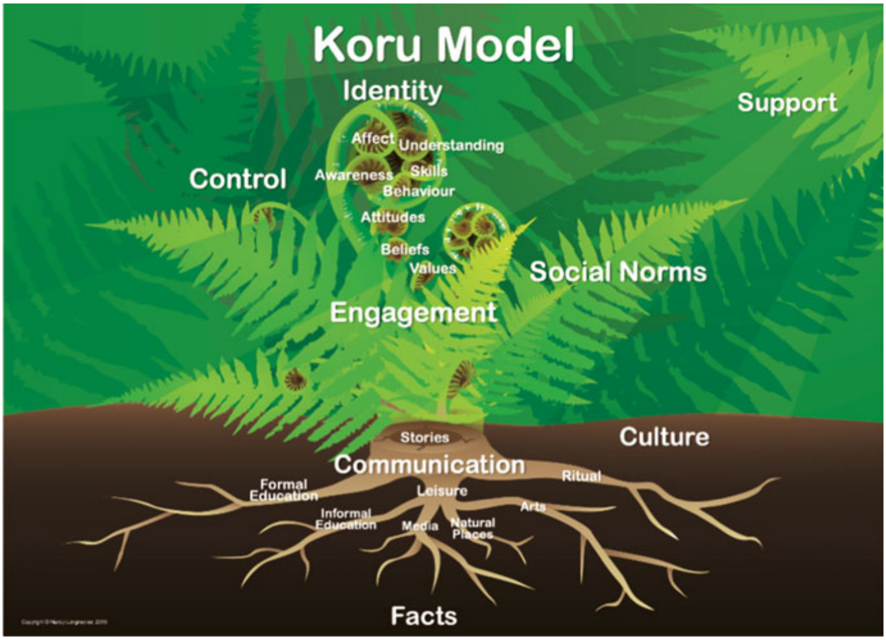

Fig. 3.1 The Koru Model of science communication illustrates that audience engagement with information is impacted by internal identity factors and external factors (culture, communication channels, social norms, control, and support) (Longnecker 2016)

spectrum of individual views. When there are strong and vocal dominant views within an audience, perceived social norms are likely to impact individual response. Engaging with the audience is especially vital in communication about controversial or risky topics. Something as simple as acknowledging an audience concern can sometimes resolve an otherwise fractious encounter.

3.6 Communication Channel Should Match Audience Preferences

In developing the Koru Model of science communication (Fig. 3.1), I returned to my academic roots in plant nutrition. Social culture is represented as the root system in the Koru Model, with different communication channels depicted as various roots. Through these, nutritious facts can be converted to information and made available to individuals. The most appropriate communication channels vary for different audiences. One assumption of the Koru Model is that individuals are interconnected through social culture in analogy with the connection of plant roots in an ecosystem, enabling two-way communication.

3.7 Focus on the Individual

A good communicator must remember that any audience is not a monolith. An audience may be a single individual but is usually many. Each individual has a sense of their own identity which affects their engagement with any communication. Communication of information that conflicts with one's sense of identity may be ignored or rejected.

In the Koru Model, an individual audience member is depicted using the metaphor of an unfurling fern frond, the Koru. The Koru is a symbol in the Māori culture of Aotearoa New Zealand for growth and new life. An assumption in the Koru Model is that an individual's internal factors (discussed below) affect whether and how they interact with new information. External factors also affect audience members' engagement and use of information, including culture, social norms, external support, and personal ability to control response.

Values and beliefs are identity elements that are persistent and difficult to change. Core values such as honesty, commitment, health, success, responsibility, friendship, loyalty, and freedom will vary from individual to individual. The hierarchy of different values will vary with the individual and can vary with circumstance. For example, an individual may place a higher priority on freedom than health or responsibility. But a brush with a fatal disease may elevate their valuing of health. Values are the foundations that influence other key factors in an individual's perceived identity.

Attitudes, awareness, understanding, and skills are more mutable identity components. Changing these is the objective of many science communication efforts (Bell et al. 2009; Metcalfe 2019). Changing **behavior** is more complex than simply providing facts or even changing attitudes. Persuasive communication that aims for behavior change is an ultimate goal of much science communication, including environmental and health communication (see Thaler and Sunstein 2017 for insightful discussion written for a wide audience).

Identity forms at a young age and some values, beliefs, and attitudes are more malleable in young people. Audiences for relevant science communication are often school groups since they are readily identified, and can be easier to reach than a wider public. Much science communication focuses on young audiences, with aims to change attitudes early and have long-term impacts.

Another common aim of science communication is persuasive communication with adults who are likely to have more entrenched values, beliefs, and attitudes but may be in positions to make short-term decisions that impact individual behavior or organizational or social policy. Pertinent examples here include communication about vaccination, new technologies, and sustainability initiatives.

3.8 Audience Level Needs to Match Communication Objective

An appropriate audience level for a communication effort will depend on the objective. The appropriate audience level for targeted communication may be the individual, society, organizations, or government.

If an objective involves changing attitudes or behavior, situated within a decision-making ecosystem where an individual has control, the appropriate audience level may be **individual decision maker**s—those who make decisions for themselves and perhaps for other family members. Appropriate communication may involve mass media (traditional and/or social), participatory or citizen science, education, or outreach programs.

If the objective requires broad action, the appropriate level for communication may be **societal** and can usefully involve influencers and consideration of **social norm theory** (see Cialdini 2021). One example of potent influence is Greta Thunberg's impact on energizing climate change activism. The youth marches for climate change action illustrate increased awareness, mobilization, and activism. As Sabherwal et al. (2021) note in their study in the United States, awareness of Greta Thunberg and her influence on intention to act on climate change was connected to motivation for collective action. In their study, the strength of influence was stronger in those with a similar political ideology, but surprisingly did not differ with respondents' age. In attempting to change attitudes in fractured societies, it is likely to be useful to consider use of different influencers with different target audiences.

If an objective involves changing the decision-making ecosystem, the appropriate audience level may be the organization or government, with the specific audience for communication being a smaller number of key **policy influencers or decision makers**. The appropriate mode of communication is likely to be very different than the mode for individual decision makers and may include lobbying, campaigns, and personal communication.

Often, communication needs to occur at multiple levels to effect change. Deciding where to place one's communication efforts will depend on the communicator's resources, skills, and specific objective(s). Setting up a false dichotomy in relation to efforts for individual behavior change versus a system approach can be counterproductive (Sniehotta et al. 2017). This can dampen efforts and enthusiasm from people who might otherwise be allies or at least sympathizers.

3.9 Culture and World View

Science communication can be considered a form of culture, as compellingly argued by Davies et al. (2019). This expands science communication beyond the utilitarian and considers it as a creative part of a culture that contributes to meaning-making among participants. Taking a broad view of potential sources of knowledge, including indigenous and local knowledge as well as Western science, allows for breadth and depth of meaning-making (Hikuroa 2017; Manyweathers et al. 2020; Tengö et al. 2021).

When different forms of knowledge are seen as disparate and separate (Gondwe and Longnecker 2015a, b), this can lead to segmentation of knowledge (Aikenhead and Ogawa 2007) and even alienation (Manyweathers et al. 2017). Communication approaches that are participatory and involve a longer time frame can allow for development of trusting relationships (e.g., Cisternas et al. 2019). They might include co-design to increase opportunity for relevance and equity (Durall et al. 2021). Building relationships has the potential to improve communication outcomes for all participants.

3.10 Equity and Inclusion

Considering equity and inclusion in science communication is an important part of broadening the culture of science and its communication. Participants in science communication are often comprised of the dominant culture, with the result of excluding and marginalizing "others" (Archer et al. 2021; Dawson 2018). Careful consideration of audiences can increase inclusivity (Canfield et al. 2020). Reflexivity on the part of the communicator can improve sensitivity and consideration of the audience.

As a first approximation, demographic information can help to paint a picture of an audience. While demographics are useful in describing an audience, beware of assumptions based solely on demographics. While Dawson (2018) found strong feelings of exclusion and low participation in science engagement amongst low-income, minority ethnic backgrounds in the UK, Falk and Dierking (2013) found that early childhood experience was a better predictor of museum visitation than was ethnicity, gender, or income. Dawson (2018) makes a strong case that science communication reinforces privilege. Polk and Diver (2020) advocate prioritizing equity to achieve more inclusive science communication.

3.11 Checklist of Audience Considerations to Use in Teaching

- *What type of audience is the communication activity intended for? Are they interested, disinterested, or polarized?*
- *What is the most appropriate level of audience to target for a communication activity, given the communication objective—individual, society, organization, or government?*
- *Will there be a preferred channel for communication?*
- *Irrespective of the type of audience or appropriate level, all audiences are composed of individuals.*
  - *What are audience members' relevant values and beliefs?*
  - *Are they likely to have existing awareness and attitudes about the topic?*
  - *Will they be in a receptive frame of mind? What is their affective state?*
  - *What is their knowledge about the topic? Are they likely to have existing knowledge that can be acknowledged?*

  - *If an audience member determines they want to act in response to the communication, will they have the skills, control, resources, or support needed?*
- *What are the audience's likely cultures and worldviews? Can sharing different perspectives be built into the communication activity?*
- *What are the social norms around the topic or issue?*
- *What is the time frame of the communication with an audience? Can the communicator develop relationships or is the communication likely to be time constrained?*

As you teach science students to communicate, it is important to explicitly foreground these points as they plan their communication activity. Several chapters in this book will help you do this (e.g., Chapters 14, 15, 31, 57).

3.12 Four Conclusions

First and foremost, the takeaway message from this chapter is that scientists who **communicate should consider their audience** before beginning any communication activity. Communicators should think about whom they are aiming to communicate with and why. If the audience and the objective are not well aligned, it may be necessary to change one or the other or even both.

A second takeaway is that **audiences are composed of individuals**. Consideration of key factors that affect those individuals' engagement with information is likely to lead to better communication.

A third takeaway is that **equity and inclusivity** should be considered in science communication. Who will benefit from science communication and who will not? Is there an audience adjustment that can be made so that the communication activity is more inclusive?

A related final takeaway is that it is important to consider the **culture and different world views** of an audience. One way, patronizing communication is less likely to be effective than mindful communication which involves consideration of different perspectives.

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The Social Brain and the Neuroscience of Storytelling

4

Carol A. Oliver

Abstract

Why is storytelling so powerful? Why do we remember stories so easily? Research suggests that our brains are socially and emotionally hard-wired to absorb stories. Stories help us learn and remember because they generate emotion and empathy. We know that storytelling is a useful and persuasive tool. Now, advances in neuroscience are helping us understand why our brains react differently to stories than they do to non-storied sets of information. As we teach and learn to communicate science, it is important to find stories that make the content alive, emotive, and exciting.

4.1 Introduction

What is storytelling, and what constitutes a story?

Before we dive into this question, let us address the idea of narrative, and "the narrative". *The* narrative is not a story, but *a* narrative is a story. "The" narrative is something created by a speaker—something being communicated. Politicians create "the narrative" on policy. Newspapers create "the narrative" on COVID-19. "The narrative" is the message about, and the stance people communicate around, an issue. It is ongoing with no defined boundaries, and no particular shape.

On the other hand, a story is a narrative with a clear beginning (once upon a time. . .), a middle, and an end. The beginning, middle, and end structure is a must-have feature of storytelling.

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Professor of Biology turned author and filmmaker Randy Olson characterised the meaning of the features when he finally figured it out with his own filmmaking. He calls the three elements, *And* (A; the beginning), *But* (B; the middle) and *Therefore* (T; the end) (2015). *And* this was the way things were, *But* there was a problem to face, *Therefore* this is how it resolved.

Great speeches, like Lincoln's Gettysburg address, contain the ABT formula. The producers of the animated comedy South Park would not let an episode go to air without passing the ABT test. You can see the structure in television shows and movies. Watson and Crick used the ABT formula in their seminal Nature communication proposing a double helix structure for Deoxyribose Nucleic acid—DNA—in 1953. *And* researchers have put forward a three-stranded model of the structure of DNA, *But* there are several reasons why that model is unsatisfactory, *Therefore* we propose a radically different model of two helical chains coiled around the same axis. In a few simple lines, Watson and Crick fundamentally changed our understanding of biology. Underlying the ABT formula is the story of *how* Watson and Crick unravelled the structure of DNA.

German writer Gustav Greytag first identified the dramatic story arc 150 years ago—an introduction (exposition), rising action, a climax, falling action and resolution or catastrophe (denouement). A story has a place and time that we are transported to in the telling, a character or characters to engage with, and a purpose in conveying knowledge. A story also has technique in the way it is constructed. Think of Harry Potter as he is transported out of the real world and into the Hogwarts School of Witchcraft and Wizardry—the story takes us into other people's worlds, real or imagined. It has a plot (what, when, where, why and to whom and how it is happening), a conflict, the transformation through conflict, and a resolution. Critically, it stirs our emotions—joy, horror, grief, love, anger, and wonder. Memories, experiences, characters, events and especially place all create a connection, so the listener *feels* something.

In the DNA story, Rosalind Franklin made Photo 51, the image that demonstrated the structure of DNA. Wilkins, her supervisor, shared it with Crick and Watson without Franklin's permission. She got scant credit for her work and died before the Nobel Prize was awarded. Non-scientists may struggle to connect with the structure of DNA, but we can all connect with the way Rosalind Franklin must have felt.

Braddock & Dillon define a narrative as a "cohesive, causally linked sequence of events that takes place in a dynamic world subject to conflict, transformation, and resolution through non-habitual, purposeful actions performed by characters" (2016, p. 2). This description shows us that characters are central to making a story emotionally engaging.

It is widely accepted that storytelling is our most effective, persuasive, and influential form of communication and advances in neuroscience have helped us understand how and why. Neuroscientists can peer into the inner workings of the mind using functional brain imaging and see parts of the brain light up when a story is being told.

These findings, especially those that demonstrate the brain's social nature, cast who we are in a different, surprising light. Storytelling is not just an effective means of sharing knowledge, it seems to be a way to connect our brains in an extraordinarily complex way.

4.2 Stories from Our Deep Past

Astronomers claim the oldest of all known stories is a moral narrative depicted in a group of stars called the seven sisters—the Pleiades—and a story that may have been first told 100,000 years ago (Norris, 2020). Before cave painting and writing, humans used campfire stories to share and pass on knowledge through thousands of generations—stories of the seasons, measured by the march of the sun, planets and the stars and the myths attached to them. These stories, seated in morality, shared beliefs, and important experiences, told people when to hunt, where to move with the seasons, and how to behave. Stories help us to make sense of the world and take notice of things that are important. Early on, survival depended on sharing those experiences.

The first known story recorded in writing is a poem, The Epic of Gilgamesh—a 4000-year-old tale of King Gilgamesh's adventures. Gilgamesh was supposedly one-third man and two-thirds a god. He terrorised the people of Uruk, spurned the goddess Ishtar, battled the Bull of Heaven, and sought eternal life, only to find that it eludes a human (History Channel, 2018). The story touches on perennially important themes for humans—love, power, cruelty, anger, and the need for humility. Gilgamesh may well have been a real king who ruled in Mesopotamia 5000 years ago, but the story itself is bigger than Gilgamesh the individual. It has been called "...a myth-making biography [...], a love story, a comedy, a tragedy, a cracking adventure" (Pryke, 2017). The Epic of Gilgamesh has been hugely influential in the development of later epics; very similar stories appear again in later works like the Bible (Noah's Ark and the Garden of Eden) and the Homeric epics (both the Iliad and the Odyssey). Gilgamesh himself even merits a bit part in the Book of Enoch, an ancient Hebrew apocalyptic text. He, and his story, have clearly captured the imaginations and memories of many people.

Fast forward to between 475 and 350 BC to the time of the Greek philosophers—Socrates, Plato, and Aristotle. Walk in Aristotle's worn leather sandals in 335 BC on the hot paving stones of Athens to a place in the shade where he sits with his students, expounding on the influential nature of orations. This is the home of Greek tragedy and comedy. The early Greeks had a long history of being great storytellers, and orators who aimed to create change by prompting their listeners' emotions. Aristotle said orations have three key ingredients (Chap. 2)—ethos (the credibility to speak on a subject), logos (the facts, the data), and pathos (eliciting an emotional response).

4.3 Neuroscience and Storytelling

Aristotle identified the role of pathos in storytelling more than 2000 years ago. A large body of research supports the idea that the emotional response to storytelling is the lynchpin to understanding how and why storytelling is so impactful. We experience emotions and empathy where pain and loss, or joy and happiness can be felt, whether human or animal. We process information through emotions, and "our mammalian brains continue to assess incoming data in an emotional context. Information is meaningful insofar as it evokes emotion" (Martinez-Conde & Macknik, 2017).

Remarkable evidence of our emotions' role in storytelling comes from a range of fields, but it is neuroscience that can visually show us what happens during storytelling. Experiments show that while reading, watching, or listening to a story physical changes in the chemistry of body occur (Zak, 2013) impacting the brain's neural pathways (Hasson, 2019) and they are astoundingly common to all of us during storytelling. Presentations expert David Phillips induced these neurochemical changes with just a few lines in a TEDx talk (Phillips, 2017). When my students view the video of the presentation, they report feeling those changes happening to them, and that a clear memory of the video remains even weeks later.

Neuroscientists have become more interested in the mind's mechanisms that make the brain more receptive to stories than any other form of communication. They can see what happens in storytelling inside our brains using functional Magnetic Resonance Imaging (MRI). Amazingly, results show that the storyteller's brain links with the audiences' brains (Hasson, 2019). The brainwaves sync like a mind-meld, and the participants can feel and anticipate the actions of the character in the story. The finding aligns with the theory of mind, which is universal to all humans—understanding what others do. When we share the emotional state of a story's character, we are essentially interpreting another's emotional state and is an example of the theory of mind's meaning.

We can also mentally mimic the actions of a character in our mind without taking any physical action. For example, the mention of the crunch of icy snow beneath the character's feet is mirrored in the brain in the same areas that would be activated as if really walking on frozen snow. Rizzolatti & Craighero called this neurophysiological reaction the mirror neuron mechanism and "it appears to play a fundamental role in both action understanding and imitation" (2004, p. 169).

The idea that the brain is a social organ emerged in neuroscience in the 1970s, beginning research into mapping the brain and the neural circuitry linked to social behaviour (Cozolini & Sprokay, 2006). We are naturally social beings driven by a brain that is "innately designed to learn through shared experiences" and our need for others to "help us feel safe and encourage our understanding of the world around us" (ibid, p. 11). Landrum et al. suggest that "human understanding of stories is internalised to the extent that we may not recognise how much we rely on them in our everyday lives or how valuable they can be in the teaching contexts". Also, "stories help us to learn by making the content personally relevant" (2019).

The small almond-shaped area of the brain called the amygdala is related to emotion (Davidson & Sutton, 1995) and there is a link between the amygdala and the hippocampus in memory generation (Phelps, 2004). While the amygdala and hippocampus are independent memory systems, "they act in concert when emotion meets memory" particularly in storytelling, and there is "abundant evidence that memories for emotional events have persistence and vividness the other memories seem to lack" (ibid, p. 14). That is why we can more easily recall an emotive story than a dry statement of several facts.

For example, consider a good joke that prompts a laugh; the listener remembers the joke, and then recounts it later to another listener. Negrete (2021) says the joke contains the three aspects important for long-term memory—attention (people pay attention to the joke), emotional response (they laugh) and rehearsal (if the joke is retold it must be exact to prompt the same reaction).

4.4 Brain-Coupling in Storytelling

The social nature of the brain is startling. It suggests human brains operate socially rather than as isolated individuals and the "forces between brains" shape our behaviour just as the Earth does not function as a sole planet but as an "element in a complex, interacting system of planets" (Hasson et al. 2012, p. 114). Developmental psychologist Bruce Hood (2014) would agree, describing our brains as "exquisitely engineered to interact with other brains".

Our ability to share brain waves with others is not the same as Mr Spock's Star Trek Vulcan mind-meld, but the sci-fi trope offers a useful metaphor. Experiments at Princeton University use functional MRI imagery with participants watching or listening to a story to graphically trace how an idea is passed from one person to another, from storyteller to listener. Hasson calls this "brain-coupling" because as the speaker tells a story, the listener's brain mirrors the speaker's brain pattern—and this occurs whether there is one listener or many (2019).

Imagery shows the brain lights up in response to a story, matching the storyteller and listener's brain pattern. This pattern matching occurs regardless of language, which Hasson says is surprising because languages each have their way of encoding through grammar that determines the physical structure. Nevertheless, he and his colleagues found a story translated from Russian into English had the same neural effects on English speakers as the Russian version does for Russians (Honey et al., 2012).

In another experiment, participants viewed a 40-min episode of the Sherlock or Merlin television series while in an MRI machine. The participants then related the story, necessarily condensing it but retaining the story. Some of the recounting was out of order or missed out parts. Nevertheless, when participants who have never seen the episode listen to the recounting, the MRI pattern remains identical to those who watched the episode. It is the story structure that matters. Researchers also found the more similar the brain patterns between watcher and listener subjects, the better the transfer of memories between them (Hasson, 2019).

4.5 The Empathy Molecule

The link between oxytocin and storytelling was first explored by neurobiologist Dr Paul Zak in 2004 at Claremont Graduate University in California. Oxytocin is the social bonding molecule present in the mother-baby relationship and, remarkably, oxytocin secretion also helps the storyteller and their audience feel empathy for characters in a story. Zak (2013) invites us to consider two stories. In one, a man walks through a park with his young son; in the other, the man is conflicted because he is happy in the presence of his son, but sad because the boy is dying from cancer. Zak points out that the second story is more memorable because it prompts oxytocin secretion and our emotions—the pathos that Greek philosopher Aristotle described that makes an oration so persuasive.

4.6 Using Storytelling in Teaching Science

Science does not just happen. It is done by people who are scientists. Their work is impactful, but their journey as researchers and explorers of the unknown is just as important. When we talk about science, we should also talk about the scientists, and the who, what, where, when, and why of their work. These details can form a story as powerful as any fictional adventure.

An example of a story I use in my classes is Barry Marshall's journey in proving to the sceptical medical world that some ulcers are caused by Helicobacter pylori—not stress—and are treatable by antibiotics. Frustrated that people with ulcers were sick and dying when he and Warren had found a cure, Marshall infected himself and then used antibiotics to return to health. Marshall and Warren won a Nobel Prize for their work. Think of any scientific concept or understanding that we have; inevitably you will also find a story of how we got that knowledge.

4.7 An Experience to Test Storytelling

TED talks are the stories of presenters. Chris Anderson, a TED talks curator, says there is no magic formula to these talks. Instead, the presenter's job is to transfer his or her idea into the audience's brains. The audience's brains should sync with the presenter's brain—as Hasson and his colleagues describe (Anderson, 2016).

A TED talk, therefore, seems a good way to conclude this chapter. "Making peace with the lions" (Turere, 2013) is about how a young Masai boy used a scientific approach to getting a scientific solution to defend his family's cows from persistently marauding lions. His solution saved not only his family's cows but those of his neighbours too. As you watch, try to be aware of your emotions as you hear Richard's story. Your empathy for Richard Turere's challenge—to save the family cows—will be processed in your amygdala. Then the memory (with assigned emotions) will be deposited in your hippocampus. As the boy speaks, he places you beside the fencing with him as he tries to figure out what will keep the lions away, and you are there as he finds a resolution. Even if you never find yourself in the Masai village protecting the cows from lions, it is compelling. And it is highly likely you will remember the story and share it with others. That is the power of storytelling. The link is in the references.

4.8 Conclusion

Our brains are social in nature and designed to engage emotionally with information through storytelling. Functional MRI has been used to understand the changes that take place in the brain. Research also links oxytocin to emotion and empathy for the characters in the story, prompting long-lasting emotional memories. Neuroscience research on the role of emotion and empathy in storytelling is beginning to expand our understanding of how and why storytelling is increasingly used in communication, the advertising world and more recently in education at higher and lower levels. There is much evidence of the persuasiveness and influence storytelling and its ability to help us retain memories. But like science, there is much yet to discover and consolidate in the science of storytelling. To be convinced of how this empathy is generated, watch the Phillips YouTube video link (2017) provided in the references.

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5 Establishing Trust in Science Communication

Caitlin Curtis, Nicole Gillespie, and Tyler Okimoto

Abstract

Trust plays a particularly important role in the process of science communication given the knowledge disparity that exists between the lay public and scientists. Of key importance are perceptions that both scientists and the information they generate are credible, ethical, and in the interest of public good. This chapter discusses what trust is and how trust plays a role in effective science communication, drawing on key concepts and research evidence. It concludes with practical takeaways for how science can be communicated in a way that is trusted.

5.1 What is trust?

Trust is critical to making scientific findings impactful. Scientifically untrained audiences need to trust in scientific methods and research findings, yet also be vigilant to disinformation disguised as science (Hendriks et al. 2016a). However, trust in the messenger is also critically important: the scientist, teacher, or communicator, and the institutions they represent can all influence trust in science and its application in society.

Trust can be defined as the willingness to be vulnerable to the actions of another party, based on positive expectations of the actions and intentions of that party (Mayer et al. 1995); in the case of trust in science, it means a willingness to rely on

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information and recommendations of scientific experts despite the potential risk of doing so. For example, trusting that vaccines are safe for your children, that your doctor-prescribed medicine will help more than it harms, that climate change is real and that we need to invest in alternative energies to slow global warming.

Seminal work and meta-analytic evidence indicate that trust is influenced by perceptions of ability, integrity, and benevolence (Mayer et al. 1995; Colquitt et al. 2007). These judgements form the key dimensions of trustworthiness. Applying this framework to the context of scientific information, this theory suggests that people will trust science when they believe it: (a) is accurate, reliable, and developed using sound scientific standards by credible and competent experts (*ability*); (b) follows commonly accepted ethical principles and values, such as transparent, honest reporting, researcher independence, and declaration of conflict of interest *(integrity)*; and it aims to enhance societal interests and wellbeing (*benevolence*) (Hendriks et al. 2015).

In addition to trust in the knowledge source (i.e., scientists), people may trust in the body of knowledge and information that has been created or provided by scientists. This "epistemic trust" involves interconnections between what has been said (e.g., the scientific content) and who has communicated and/or produced it (e.g., the scientists) (Hendriks et al. 2016c). In the sections that follow, we discuss key findings on what influences trust, and thus the effectiveness of communicating science.

5.2 "Who" Is Communicating the Science?

The credibility of the source, institution, or messenger influences whether or not we trust the science being communicated (Whiting et al. 2019). For example, people trust medical information coming from doctors and nurses more than they trust the same information coming from the government (Scarfuto 2020). Such credibility is not inherent to the individual communicator, but is subjectively assigned by the listener based on their perceptions of the expertise and motivations of the source or messenger (Eiser et al. 2009).

Encouragingly for readers of this book, surveys suggest that "the public" generally trust scientists and teachers (IPSOS 2019). Data from the United States show that public confidence in scientists has been stable for several decades (Pew Research Center 2020), with upswings in public trust in medical scientists during the COVID-19 pandemic.

5.2.1 Connection Between Communicator and Listener

As most good teachers know, connection is important in communicating information. The perceived warmth and goodwill of the communicator toward the audience can open a pathway to a trusted relationship (Fiske and Dupree 2014), and can encourage openness of the audience toward the communicator. This highlights the two-way nature of effective communication, where the connection between the communicator and listener helps to garner trust in the message itself. For example, research suggests that a scientist sharing their "origin story" as a first-person narrative (i.e., what led them into the research) helps the audience to identify and connect with the scientist as an "authentic" person, as well as providing insight into their motivation as a scientist (Saffran et al. 2020; see also Chap. 43). Humor, in some circumstances, may also boost perceived trustworthiness, by enhancing one's perceived expertise (Yeo et al. 2020).

Group-based connections can also affect trust. When the speaker and listener share a "social identity" (i.e., a valued group membership), the listener is more likely to presume shared values and goals, trusting the communicator and the message more than when they do not share a group membership. Social scientists refer to this as the "individual-group discontinuity effect" (Ferrin et al. 2008); describing the phenomenon that trust is consistently lower across intergroup boundaries.

5.3 "What" Is Being Communicated?

5.3.1 Complexity and Uncertainty

Trust is particularly critical for communicating science that is complex (not intuitive), unwelcome, or has implications that require behavioral change (Siegrist 2019). For example, the science around climate change is hard to accept because it is complicated, it has implications for the self (e.g., "I'm contributing to the problem," "it makes me anxious"), and calls for behavioral self-sacrifice (e.g., "it is costly to comply"). Trust in scientific experts or their information can reduce the perceived risk of making complex decisions (Brewer and Ley 2013). Being transparent and openly communicating uncertainty can also improve trust, although this can vary among individuals and contexts (van der Bles et al. 2020).

5.3.2 The Scientific Method

Some inherent aspects of the scientific method can challenge trust. For example, the fact that scientific results can change over time, are not always replicated, or can evolve with new findings, may challenge trust and heighten perceived ambiguity around scientific findings. In the classroom, students' trust can be improved by their understanding of peer review, scientist credentials, degrees of expert consensus, the potential for scientific bias, and critical evaluation of sources (Leung and Cheng 2021, see also Chapters 36, 58, and 66). In public communication of science, signals of trustworthiness include transparent data and methods, funding disclosures, and publication in peer-reviewed journals (Jamieson et al. 2019).

5.3.3 Conflicting Results and Consensus

Conflicting results can also be problematic for trust. They are particularly influential if an individual has a reason to distrust the information, leading to *motivated reasoning*—where presupposed assumptions or desires can bias information processing (Kunda 1990). Trust in science is particularly low when findings push against existing values, ideologies, worldviews, religious, and/or political beliefs (e.g., Druckman and McGrath 2019). Socially relevant science (e.g., environmental pollution, vaccines, and climate change) tends to be influenced by politics and preexisting beliefs that make trust particularly challenging (Hornsey 2020).

As a result, scientific consensus is often seen as the gold standard among both students and the wider public. For example, emphasizing medical consensus about vaccine safety seems to be an effective pro-vaccine message (van der Linden et al. 2018). However, if total agreement is claimed where full consensus is incomplete, claiming consensus can have the opposite effect and undermine public trust. Consensus with appropriately communicated caveats is more likely to support sustained trust (e.g., "The large majority of the immunology community agree that. . ."), although it does open the door for motivated skepticism.

Importantly, science is also not always perfect. Although perceived expertise *(ability)* has been shown to decrease when scientific flaws are disclosed, *benevolence* and *integrity* increase when the flaw is self-disclosed, rather than being revealed by others (Hendriks et al. 2016b).

5.4 "Why" Is the Scientific Information Being Communicated?

Trust is influenced by the why: is the science perceived as being communicated for benevolent reasons (to benefit others and society), or malevolent reasons (to manipulate, e.g., for political reasons)? As such, the perceived independence of the research and its reporting, and transparency of any conflicts of interest related to the science are key.

Individuals report higher trust when they believe that scientists are motivated to inform rather than persuade people to take an action, suggesting that the public places trust in impartiality (Rabinovich et al. 2012). Fortunately, best practice in science is to train scientists to be skeptical about their own work, communicate limitations, specify what is and is not generalizable, and what further research is required. However, scientific advances are also linked to a scientist's career success. This may lead researchers to overstate implications or conclusions, particularly with the ongoing pressure for research impact and importance, and the desire by the public and industry for simplicity and clear takeaways. Despite these pressures, avoiding hype is important (Intemann 2020) because overselling can damage trust in the longer term.

5.5 "How" Is the Science Being Communicated?

Historically, communicating science was treated as a one-way flow of information: communicators provide information in a digestible format for audiences to absorb and act on. This one-way approach is called the "information deficit model" (e.g., Suldovsky 2016). However, modern approaches recommend two-way dialogue is more effective (Reincke et al. 2020).

Communicating as part of a two-way or participatory process helps establish trust between the communicator and audience by increasing a sense of shared values, goals, and facts, which may be particularly beneficial in supporting decision-making (Dietz 2013). For example, scientists who blog about their work and interact with their readers about the associated ethical implications are perceived as more trustworthy by readers than those who do not. The impact is greater if the scientist raises the ethical issues themselves, rather than being raised by an outside expert (Hendriks et al. 2016c).

5.5.1 Inclusive Science

Whether in the classroom or in the broader public, two-way communication is also critical to engendering inclusivity when it comes to the search for scientific truth. While inclusive dialogue can enhance trust, feeling disconnected, excluded, or unwelcome in the scientific dialogue can create marginalization or mistrust. Many communities and groups remain underrepresented in both the scientific endeavor and dialogue. A more inclusive diversity of voices and spaces in communicating science would likely encourage greater trust and connection to science. Examples of concerted efforts to enhance inclusivity and diversity are emerging in some areas, such as the visibility of female scientists (McCullagh et al. 2019) and cross-cultural conceptualizations of science communication (Orthia 2020).

5.5.2 Reflexive Science

Two-way dialogue also has the potential to improve science itself. Reflexivity in science (Salmon et al. 2017) involves a researcher's ongoing and iterative critique of their work, checking assumptions that underpin the work and the possibility of biases. Reflexivity can be improved through dialogue with science consumers; the interaction may serve to check researcher biases and assumptions not detected by scientists who may share those assumptions. Genuine and transparent dialogue can also create a channel by which audiences feel "heard" and connected to the science. Likewise, modifying the structure and content of lessons to meet the characteristics of students (i.e. "adaptive teaching") has been shown to have a positive correlation with students' performance in science in many countries (Mostafa et al. 2018).

5.6 Practical Takeaways for Communicating Science in a Way That Engenders Trust

Below are some starting points to use when teaching students how to engender trust in their science communication, as well as to improve our own practice.

1. *Consider your audience*
   Considering your audience and delivering information tailored to their needs is a first step in building trust and effective communication, including in the classroom. Breaking down language barriers and reducing complexity can foster understanding between the communicator and the audience. Speaking in a way that is clear, understandable, free of scientific jargon, and tailored to the audience you are communicating with can help bring people along (see Chapters 3 and 19 for more details).
2. *Communicate the "why"*
   Focus on the meaning and convey the relevance of the science to the audience to promote a shared understanding of common goals and benefits. Connecting research, data, and results together through narrative and storytelling can be a valuable way to help students relate to the research, and a useful tool to tie it to a broader theme—such as climate change (see Chapters 20 and 45 for more details).
3. *Break down complexity*
   Many audiences, including students, benefit from communication where the headline scientific findings are presented in an understandable way, and then "lifts the lid" by explaining in more detail how the science works. It breaks complex topics into small pieces—supported with visual aids or relating to common ideas (see Chapters 26 and 53 for more detail). Although many scientific topics are highly politically charged, nonaggressive messaging works best (König and Jucks 2019).
4. *Educate about the uncertain nature of science*
   Explain key processes, procedures, risks, and methods of doing science so that audiences can understand. Give context and perspective about the limitations of the science, as failure to do this can undermine trust in the longer term.
5. *Relate the scientist to the audience*
   Scientists are normal people and we are more relatable and trustworthy when we present ourselves that way—as trustworthy, human, good, and "normal" people with lives and interests (see Saffran et al. 2020). This can even be done on social media.
6. *Encourage dialogue and inclusivity*
   Interact with your audiences through genuine conversation and dialogue. Listen. Reflexive science, including taking on the perspectives and concerns of the public, can help to resolve inconsistencies in understanding (for more detail see Chapters 34 and 55).

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Critical Appraisal and Evaluation of Information

6

Kate Mercer, Kari D. Weaver, and George Lamont

Abstract

The way information is communicated is inextricably linked to how it is found and understood. Tied to this are the realities of changing and overwhelming information landscapes. To communicate effectively, students must be taught to navigate the information deluge and be critical of information, regardless of origin, complexity, or purpose. This chapter introduces a process of critical evaluation of information that can be used when teaching science. In doing so, we articulate the main phenomena that influence how people—namely students—find, use, and disseminate information, and emphasize the importance of training students to critically evaluate ALL sources of information. Our aim is for students to become effective communicators by incorporating the process of critical evaluation of information into their practice.

6.1 Finding Information

Last time you didn't know something, where did you go for information? Was it another person, a written resource, or the internet? Quite possibly, it was the internet, which is full of cheap, contextualised, and easy-to-access information (Rowlands et al., 2008). Some of the information is correct. Some of it is not. You sifted through it, found the information you needed, and then discarded other items.

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Perhaps you wondered which information was trustworthy, or perhaps you could apply your own expertise to decide what information to use. Perhaps you got distracted by an interesting link and spent time swimming in the information sea you encountered. You may even have been lured to particular links by a carefully crafted, personalised and paid information campaign. As Gleick (2012) reminds us "when information Is cheap, attention becomes expensive" (p. 410).

Even for the most experienced of us, finding and evaluating information is a significant task. For learners, information is exciting, but it can also be confusing and overwhelming. For educators, engaging and maintaining student attention is one of the most challenging aspects of teaching. Students face not only an overwhelming amount of information in courses and labs but also competing "popular" information. Studying textbooks vies with social media, and one is definitely easier to consume than the other!

By the time they reach undergraduate studies, many students have developed ingrained habits around finding and consuming information from the vast data universe. In some cases, this can mean students are not reading or using information critically.

Now that information is ubiquitous, fed to us by algorithms, and sourced from multitudinous creators, we must encourage students to question where they find information (and whether it is trustworthy). Predatory publishing is undermining the quality of journal articles, peer review is flawed, and bloggers can be highly-educated experts in their fields. It is no longer enough to teach students that Google is "bad," and the library catalogue is "good", because that is not necessarily true.

6.2 Is Teaching Information Literacy the Answer?

Rooted in the field of Library and Information Sciences, Information Literacy (IL) is the "set of integrated abilities encompassing the reflective discovery of information, the understanding of how information is produced and valued, and the use of information in creating new knowledge and participating ethically in communities of learning" (Association of College and Research Libraries, 2015, p. 9). IL is intended to have broad relevance across academic disciplines, but *teaching* IL is often limited. Many of us have invited the librarians to give a presentation about finding information resources pertinent to a course or assignment (Cruickshank, 2019). We might also have showed students how to use some online tools for searching and referencing information. Often, we don't go further than this when we consider our students' IL.

Teaching of IL has had uneven uptake and impact in higher education, in part because there is debate about its place as a legitimate discipline (Webber & Johnston, 2017). What we can say, however, is that information, and the ability to use it effectively, is critical to modern scientists. This is because we now all live in the information society, a place in which the creation, communication, consumption, and use of information is the defining feature (Oxford Reference, 2022).

6.3 Critical Evaluation of Information: A Better Fit for STEM

As noted above, information literacy involves "use of information in creating new knowledge and participating ethically in communities of learning". Before students can be truly information literate, they need to be able to evaluate whether the information they want to use is valid. This is particularly important in an age when the public is questioning science. As scientists, our ethical participation in society is predicated on the idea that we communicate trustworthy information. Consequently, teaching students to engage in critical evaluation of information (rather than teaching for the more overarching goal of IL) is a better fit for STEM (Science Technology Engineering and Mathematics) education.

The most widely known approach to systematically reviewing the quality of information comes from the health disciplines, which use a process called critical appraisal (Young & Solomon, 2009). Critical appraisal provides a systematic, checklist-driven approach to assess the quality of a research project's design, question, data analysis, and findings. Critical appraisal also helps to ascertain the applicability and validity of a project's outcomes to a research or clinical task (Twells, 2015; Young & Solomon, 2009).

Critical appraisal in health disciplines assumes individuals possess strong background knowledge in the health fields to identify and align the criteria properly. In STEM education, however, students need to work from an interest in the sciences, to broadening their education, and finally arriving at a fulsome understanding of science. Consequently, student scientists may not yet have the disciplinary knowledge required to engage fully in critical appraisal of research and research findings.

As students study science, they become more and more aware of the discovery processes in their discipline of choice. It can take longer, however, for them to become highly conversant with the pressures and practices of the research environment. Critical evaluation of research involves questions about why the researchers are doing the project, who funds them, and how their work fits into the contemporaneous scientific conversation. The use of a structured critical evaluation approach helps students ask these questions as they assess the quality and validity of a research study (Lamont et al., 2020).

Two popular frameworks that help students critically evaluate information sources are RADAR (Relevance, Authority, Date, Appearance and Reason) (Mandalios, 2013) and CRAAP (Currency, Relevance, Authority, Accuracy, and Purpose) (Blakeslee, 2004). These tests use targeted words and questions to help the user determine if a source of information is 'good'. These tools are both valuable as they give students an easy-to-remember acronym along with an actionable approach to evaluation.

We have recently proposed a formal Critical Evaluation of Information (CEI) approach that incorporates and extends RADAR and CRAAP (Mercer and Weaver, 2022). The CEI approach guides students to examine the information and its communication context, while also asking them to tie this method into their daily practice of navigating information and building scientific knowledge (Mercer &

Weaver, 2021). The CEI approach helps undergraduate students learn, build, and use knowledge so that the process itself becomes a habit (Mercer & Weaver, 2022).

We will provide more detail of the framework at the end of this chapter. First, however, it is important to consider the reasons why the CEI process is valuable.

6.4 The Influencers of Information Literacy

6.4.1 Information Overload

The term "information overload" was originally coined by Gross (1964) and made popular by Alvin Toffler in 1970s *Future Shock*. While much has changed over the last 50 years, the overall concept remains important: when people are overwhelmed with information, decisions become overwhelming. In an overwhelmed state, navigating any decision can be difficult; navigating an important decision (should I get vaccinated?) can be paralysing.

Massive amounts of new information are being created, and there is pressure to create, disseminate, and understand information at an unprecedented level. This information creation is coupled with a phenomenal increase in the ways we can receive information. We are now bombarded with social media, radio, television, print, websites, email, texts, and in-person conversations that present contradictory and increasingly inaccurate information (O'Connor & Weatherall, 2020). We are all influenced by our educational backgrounds, our families, and our peers; however, information consumption in this new world is often tied to fear and a systemic inability to fact-check at the scale we now must navigate (Mahdi et al., 2020). To combat information overload in a classroom and beyond, people need concrete approaches to process, compare, and evaluate different information sources.

An overwhelming amount of information encourages people to analyze the information from their most comfortable viewpoint (Dalkir & Katz, 2020). The desire to create this comforting truth results in doubling down on one's own biases; it becomes easier to believe in a fake news conspiracy than acknowledge that one may be wrong (Bartlett, 2020). Students often ask educators things like, "Aren't you biased as well? How do you know you're right? How do you know vaccines don't cause autism, isn't that your bias?" Information, and the validity of it, is increasingly becoming a morals-based platform.

We need to cultivate the mindset that it is acceptable to step back from an overwhelming amount of information, acknowledge the confusion, and give the right issues the attention they deserve.

6.4.2 Misinformation

We cannot disentangle information overload from misinformation. Terms like "fake news" and "alternative fact" are becoming so commonplace that we are desensitized to their absurdity (Zimdars & Mcleod, 2020). What we are willing to consume, and to believe, is skewed by things like our political affiliation, fear, internalized bias, and existing values (Dalkir & Katz, 2020). These influences make it difficult to disentangle information-vetting practices from social groups and, in fact, from personal identity (Narayanan et al., 2018). Debates over scientific facts like climate change, vaccinations, and disease transmission exemplify how beliefs are often shaped by people we think we know and trust (Gabbert et al., 2004). Increasingly, targeted social media attacks are used to influence us and feed us convincing untruths (Kiely & Robertson, 2016).

When teaching communication in STEM, we are often left questioning: how do we teach and communicate fact, when fact is now seen as subjective? One way to address the fluidity of facts is help students ask why information is being communicated, and how it is being used to influence people.

6.5 What Does This Mean for Teaching Science Communication?

In the era of information overload and misinformation, science needs effective communicators who can process large quantities of dissonant information. As science teachers, we need to help students make decisions about which information to use. The information we need to consider now routinely includes non-peer-reviewed, non-journal article data, opinion pieces, blogs, and bite-sized tweets.

Approaching and validating this "unsanctioned" information can be uncomfortable for scientists, but we believe the CEI methodology can be useful. We return now to unpacking the CEI approach; it has four steps that, together, allow Critical Evaluation of Information.

Step 1: Define context—the user identifies and clarifies the context in which information is presented. An understanding of the context will shed light on the motivations around why and how the information is presented. Understanding context (and considering who is communicating) can prompt an information user to examine how the speaker's authority has been constructed (and who sees them as an authority). Understanding context also helps the user consider why they might choose information from the context. For example, when investigating climate-change denial, it is useful to use information from a climate-change-denier's blog. The user can examine the way information is used to make an argument in this particular context.

Step 2: Find a source—this step goes hand-in-hand with understanding the context. The user finds a source that has value for the topic they are investigating. As part of this they can consider what kind of information this source may give, and which part (or side) of an argument the source addresses. They can also consider what additional sources the source draws upon. Importantly, the source does not have to be a peer-reviewed journal. All sources are worthy of investigation in the CAI model.

Step 3: Use any Evaluative Framework—users then use any framework (e.g., RADAR or CRAAP) to evaluate the source and its data.

Step 4: Critique/Applying Scientific Method—the user critiques the source and data, drawing on their personal experience of the topic, the evidence of scientific process, and their answers to the evaluative framework questions. This critique can be done individually, or as a group discussion. As part of the critique, the user includes a discussion of the context and the communicator who produced the source.

Together, these four steps do more than just examining the validity of a piece of information from the perspective of "science" and the scientist's process. They also address the context in which the information is presented, and ask the user to consider why and how the information appeared in that context. The user is also invited to share their own personal experience of the issue under investigation, and to express an opinion about the information. All of these steps make the user more able to confidently discuss the data (and its use) and explain it to others.

6.6 Conclusion

Science uses information to provide context, to shape questions and hypotheses, to situate the researcher in what is known and unknown, and to effectively disseminate findings and ideas.

While the idea of information literacy aligns with the needs of science, the terminology and present practice of information literacy in higher education fails the needs of both students and the scientific community at large. Because information influences how we conceptualize, shape, and ultimately communicate in science, teaching scientific communication must emphasize the integral role that information plays in shaping how people understand science.

Some institutions have worked to address these issues, but the education about information in the sciences cannot be relegated to the common intervention of a single visit by a well-meaning librarian (Fuselier et al., 2017). Instead, these efforts must be undertaken in a more collaborative manner throughout science curricula to work explicitly with students to digest, evaluate, and accurately disseminate information. Adopting and modelling the use of tools such as the RADAR and CEI frameworks can provide guidance for critically evaluating information. This is a far more flexible way to improve students' information use than a blanket attempt to control where students obtain their information.

We are not making an argument against the use of Google, but we do acknowledge that, in many social and professional contexts, people default to using the most accessible information as a matter of course. Pedagogy and teaching need to catch up to the idea that if (and when) students Google something, science demands they must also undertake a formal process of critiquing what they find.

In a world where people are used to fingertip-fast answers, it is a radical step to pause. We encourage you and your students to do it! Learning to think deeply about the information we choose to use is essential to our development as scientists and as communicators.

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Data Visualisation

7

Phillip Gough and Jack Zhao

Abstract

Data visualisation is an effective tool in the scientific process that can also be a powerful tool for communication. The challenge of visually communicating data often comes from different levels of literacy possessed by our intended audience—from field experts to policymakers to the general public. While there are many useful tools to visualise data, providing value to a diverse audience requires a user-centred approach. In this chapter, we discuss "good" visualisation. From understanding your audience and context to principles essential for creating and evaluating a visualisation, this chapter will take you through the key considerations in the iterative development of a valuable and effective visualisation.

7.1 What Makes a Good Data Visualisation?

Data can come from a wide variety of sources—physical activity trackers, national census surveys, scientific research, and medical epidemic data studies, just to name a few. It is estimated that the volume of digital information across the globe doubles every two years (Gu et al. 2016). The value in data comes from gaining new insights. However, this presents a real challenge, as the mental agility required to make sense of even modest data sets can be quite high. So, data is plotted to leverage the human brain's amazing capacity to make visual comparisons quickly without conscious effort.

Scientists turn to data visualisation during all stages of the scientific method for insight and communication. But a well-designed visualisation, or a "good"

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visualisation, provides the benefit of data-driven insight to a broad range of audiences in varying contexts. A good visualisation combines an understanding of three things: (1) graphical techniques to put the data on a page (or screen) so that it can be interpreted, (2) the important and valuable message that is available from the data, and (3) the audience (who will see the final figure) and the way they will see it).

When teaching or creating data visualisations, people often start with plotting data. But this approach is contrary to how successful digital products, including data visualisations, are designed. The first step in presenting data is to build an understanding of your user and their context (Grainger et al. 2016).

Data visualisation led by what the intended users need employs a user-centred, rather than data-centred approach. The idea is not to reduce the importance of data, but to present the essential message from the data visualisation while considering user's needs and context. This helps us create the best data visualisation for the people who will see it.

The user-centred approach requires more effort, but it will help make a "good" visualisation. We will describe user-centred visualisation through three sections. First, we discuss different audiences, and the value your visualisations will give them. Then, we will look at priorities that inform how a data visualisation can be constructed. We finish with some guidance about evaluating data visualisation. We will include some of the underpinning theory that forms the foundation for any good visualisation, discuss real-world examples, and look at the whole visualisation design process.

7.2 Start with the User

There are two practical benefits of data visualisation: comparisons and connections. Giving a visual form to abstract information makes data seeable, so the user can make comparisons. Data that is plotted is more easily understood than tabular data. A classic example is Anscombe's Quartet. Figure 7.1 left shows four sets of numbers; each set has similar descriptive statistics (such as their mean and standard deviation). The tables show how difficult it is to tell the difference between even simple data sets. The same data are plotted in Fig. 7.1 right; it is immediately obvious how the sets differ, and the comparison requires no conscious or cognitive effort. Anscombe's Quartet is typically used to learn about regression in statistics classes, but this example clearly shows how much easier it is for someone to make a visual rather than mathematical comparison.

The second benefit of data visualisation is the connections between the data points that become clear. Visualisation helps the user form a mental image of the structure of data, the patterns, relationships, and connections within the data set (Manovich 2011).

But not every audience is the same, so understanding them helps you create the most appropriate visualisation. The target audience can be broadly profiled in two ways: by their topical and technical literacy on a continuum from *novice* to

Anscombe's Quartet

I		II		III		IV	
X	Y	X	Y	X	Y	X	Y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

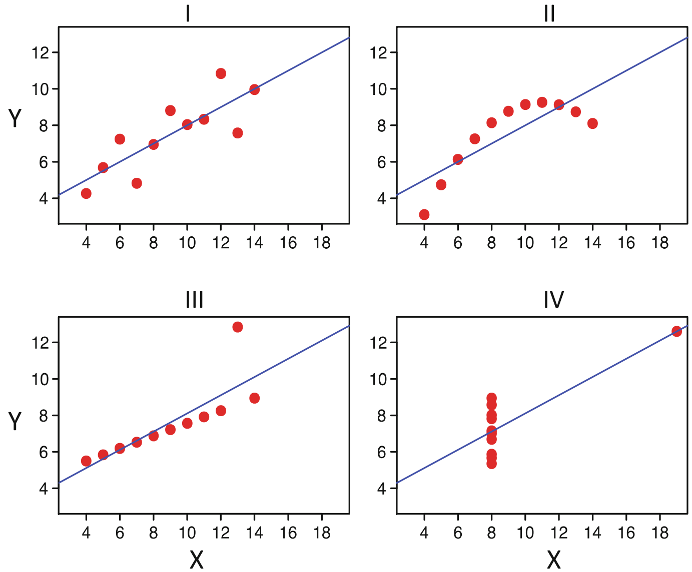


Fig. 7.1 Anscombe's Quartet, showing how data (left) with similar descriptive statistics can still vary significantly, which is easily compared in the charts (right)

Table 7.1 Example applications of data visualisation for expert and novice audiences

Audience Expertise	Use Context	Example
Novice	Task-driven	Visual tools to support students learning science
Expert	Task-driven	Analytical tool used during the scientific process
Novice	Narrative-Driven	Communicating results to a range of audiences, such as policymakers, popular science articles, or for promoting science
Expert	Narrative-Driven	Publication of results in academic literature or grant applications

expert; and by the context under which the data visualisation is intended to be used, on a continuum of *task-driven* to *narrative-driven* (Table 7.1).

For example, data experts may be scientists visualising data or reading a research paper, or clinicians using medical data to make decisions about patient treatment. These groups have deep expertise in the field of the data and an external motivation to use the visualisation—usually, their work. Data visualisation research generally focuses on pragmatic goals of this audience: usability, performance, accuracy, and memorability (Borkin et al. 2013; Saket et al. 2016).

A non-expert in the field of data does not have the same motivations to use a data visualisation. They may see a visualisation at a museum, on social media or from their physical activity tracker, which makes their context arguably more complex. Visualisation attached to a news article will need to engage a general audience who may have other information competing for their attention (Bateman et al. 2010; Heller 2006). For non-expert audiences, *what* should be visualised is an important question. It can help the data visualisation engage its audience, tell a meaningful story, provide a point of engagement with a complex issue, such as climate change, but can still be used as an analytical tool (Byrne et al. 2017).

By critically reflecting on the needs of the audience, the visualisation can be tailored to meet their needs. Helpful questions to ask (Gough et al. 2016) include:

- *What in this data is particularly difficult for your audience to access or understand?* This outlines what should be explained in detail and gives novelty to the user.
- *Are there any myths or misconceptions that are relevant?* The "backfire effect" may alter your user's understanding of your data.
- *Where is the potential for impact, or for the risk of misunderstanding?* Reinforce what might give the user some benefit and clarify what might be misunderstood.

Figures 7.2 and 7.3 show different approaches in action. Figure 7.2 aims to inform experts and policymakers, helping shape their responses to the COVID-19 pandemic. The map highlights places that have significant correlations between two social-economic datasets. The circle overlay shows the impact of the pandemic in terms of cases and deaths. Although some background knowledge is required to

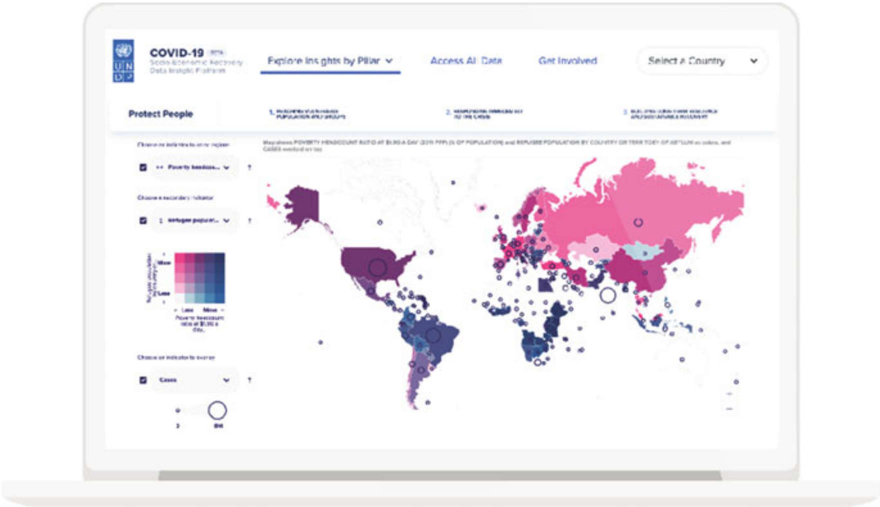


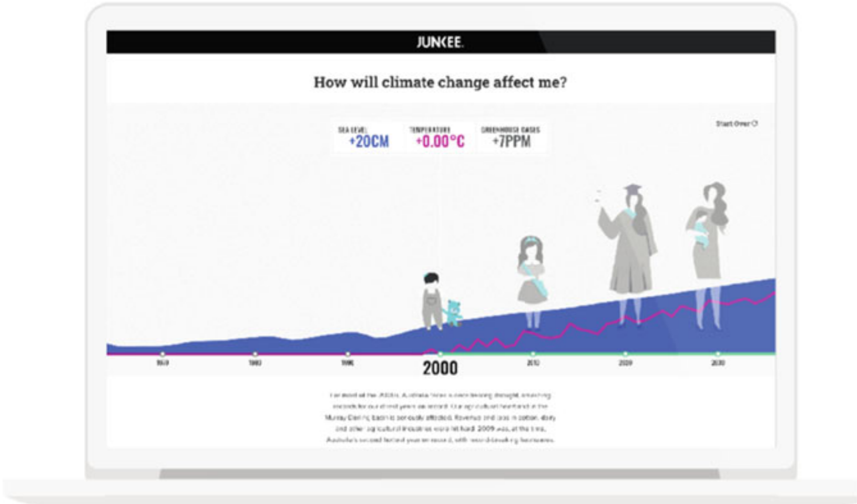
Fig. 7.2 COVID-19 Socio-Economic Recovery Data Insight Platform. Copyright Small Multiples 2020. Available online: https://smallmultiples.com.au/projects/covid-19-socio-economic-recovery-data-insight-platform/

construct meaningful bivariate combinations, the default map view is still useful to the public (novice users) as a snapshot of the combination of pre-existing issues and damages from the pandemic of a country.

Figure 7.3 engages and guides a novice audience using a narrative throughout the visualisation by combining simple, guided interactions with relatable graphics. This interactive timeline asks the user for their birth year and visualises the changes in temperature, sea level and greenhouse gases over their lifetime. Although these two visualisations take different approaches, each aims to provide value relevant to their intended audiences.

7.3 Value for the Audience

There are multiple ways to consider the value and effectiveness of a data visualisation. One perspective is that effective visualisations are both *informative* (useful, complete, perceptible, truthful and intuitive) and *emotive* (aesthetic and engaging) (Few 2017). The value also changes between an expert or non-expert



How will climate change affect me? - Junkee
Audience: Made for novice or lay audience, primarily the general public.
Usage: Narrative-driven, designed to support a special report.

Many young people today will live to see the 22nd Century - and the effects of climate change will disproportionately fall on them. Junkee Media surveyed young Australians about their views on climate change, and we visualised the data. The visualisations were integrated into a long-form news article, accompanied by instructions to help the audience navigate its features.

Fig. 7.3 "How will climate change affect me"? Copyright Small Multiples 2019. Available online: https://smallmultiples.com.au/projects/how-will-climate-change-affect-me/

audience. Scientists and engineers may prefer a visualisation that facilitates deep exploration of data, using complex visualisation methods that take time to learn and understand. Journalists may prefer a shallower visualisation, that can communicate a clearly defined message to a broad audience (Cairo 2012). These different priorities show an understanding of the audience, without suggesting that one approach is correct or incorrect.

Whether a visualisation prioritises complexity or clarity, it can give value to the audience. Calculating this value is a useful activity to reflect on whether a visualisation is appropriate for the audience. The *Value* (V; importance, worth, and usefulness) of a data visualisation can be considered through this equation (Stasko 2014):

$$V = T + I + E + C$$

Time (T) is the visualisation's ability to reduce the amount of time to answer a range of questions. For example visualisations of small data sets (such as Fig. 7.1) can be useful, but visuals of multivariate data are much more valuable because they reduce the time required to interpret more data (see Tufte 2006, pp. 126–136).

Valuable visualisations provide *Insights* (I) and prompt insightful questions. Insight is the ability to recreate a mental image of the data and the relationships between data points. These relationships between data can be understood and distilled into an overall *Essence* (E) or take-away message from the data. The visualisation should also generate *Confidence* (C) and trust in the data itself: in its source and its validity (Stasko 2014).

By scoring each element out of 10, you can understand the priorities and trade-offs made by the creator. This examination of value as a quantifiable construct demonstrates the importance of considering the context of the user.

7.4 Seeing Without Thinking

With the user and context in mind, we can turn our attention to planning the design of the visualisation. We will discuss two strategies to help increase the value of a visualisation by reducing the time (T) the audience needs to interpret the visualisation. The two strategies are:

1. Designing for *preattentive visual processing* to ensure the information is conveyed quickly without conscious effort and.
2. Using *gestalt principles* and the *information-seeking mantra* to help reveal patterns with fewer elements and minimise information overload with interactivity.

We will first explain the principles, then demonstrate their use in the next section.

Visualisation works because the human brain has evolved to process visual changes in the environment quickly, without requiring conscious decisions or dedicated attention (Few 2009, Chap. 2; Ware 2021). The common preattentive visual attributes for data visualisation are outlined in Fig. 7.4. The attributes can be applied simply or in a more complex and subtle manner. Anscombe's Quartet (Fig. 7.1) puts preattentive visual processing into practice simply, primarily employing 2D-position. The COVID-19 recovery visualisation (Fig. 7.2) is more complex—it primarily uses colour, size, and position of graphical objects as preattentive visual attributes.

Gestalt theory explains how humans perceive and recognise patterns by organising individual elements visually into structures and groups using proximity, similarity, continuity, closure, connection, and enclosure. Data visualisation can leverage Gestalt principles to convey meaning through the organisation of visual elements (Hicks 2009). The case study in Fig. 7.5 illustrates how some of the Gestalt principles can be applied to the design of data visualisation.

Data visualisations also benefit from organising information into a hierarchy, prioritising what needs to be shown. This hierarchy is created by first reducing the information that is shown, and then assigning data to variables: the most significant

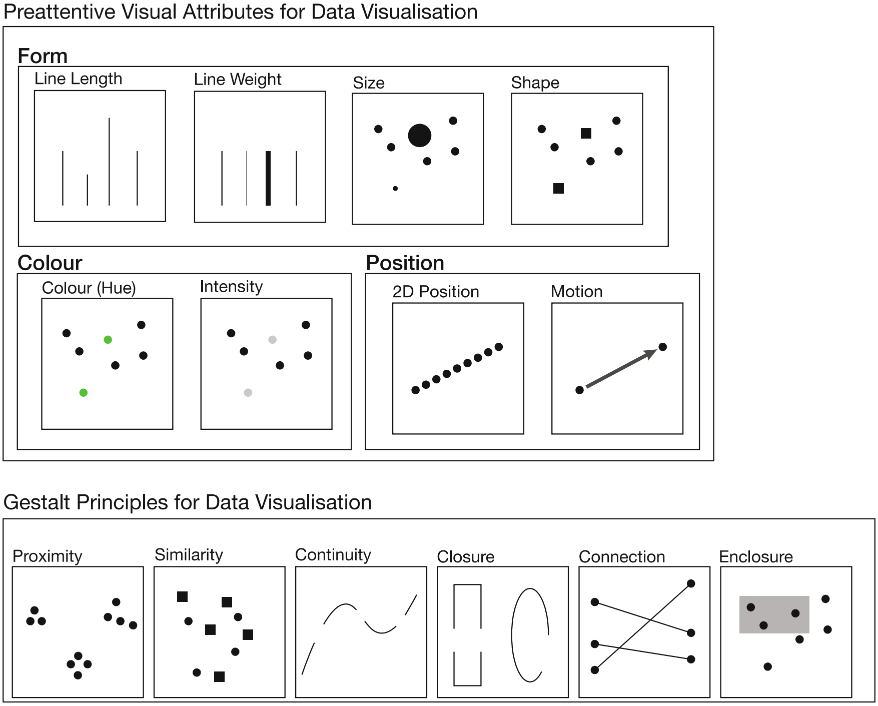


Fig. 7.4 (Top) Preattentive Visual Attributes, adapted from (Few 2009), and (bottom) Gestalt Principles that are applied to data visualisation (Hicks 2009)

and important variables are assigned to spatial variables, such as 2D position or line length, and information of lower importance is assigned to visual variables, such as colour (Manovich 2011). This hierarchy adds value for the user by facilitating the overall essence or take-away from the data. In practice, The Visual Information-Seeking Mantra describes an effective approach: "Overview first, zoom and filter, then details on demand" (Shneiderman 1996, p. 337).

7.5 Designing with Visualisation Principles

Design plays a significant role in data visualisation, especially when creating entirely new representations of data (Vande Moere and Purchase 2011). When creatives (such as designers) and data experts (such as statisticians) collaborate, they can visualise data from fun topics and pop culture (see https://pudding.cool/) through to issues as serious as gun violence (see https://guns.periscopic.com/) (Citraro and Rees 2015).

In Fig. 7.5, we show The Multi-Omics visualiser by Small Multiples to demonstrate how principles of visualisation are applied in an interactive visualisation for an

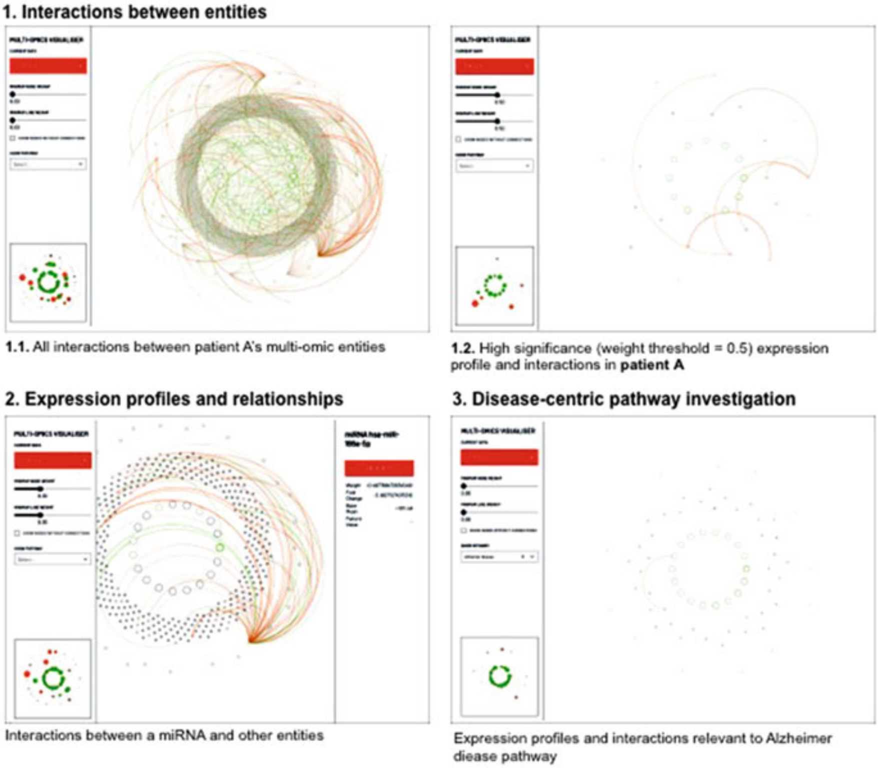


Fig. 7.5 Multi-Omic Visualiser by Small Multiples. Copyright Small Multiples. Available online at https://smallmultiples.com.au/projects/multi-omics-visualiser/

expert audience. These visualisations show networks of interacting expressed gene products to help uncover disease markers. To assist the audience, preattentive attributes and Gestalt principles are used.

The preattentive attributes in Fig. 7.5 include:

- Increases and decreases are immediately apparent from **colour** coding (Panel 2).
- Colour **intensity** depicts the magnitude of change from the norm (Panel 1.2).
- Significant connections (high absolute values) are thicker in **width** (Panel 1.1).

The Gestalt principles applied in Fig. 7.5 include:

- **Proximity:** Biomolecules of the same type (e.g. proteins) are placed closer to each other, which makes the grouping easy to see (Panel 1).
- **Similarity:** Deviations from the norm are represented by colour (increase = red, decrease = green), this reveals subsets of shared behaviour (Panel 2).
- **Connection and continuity:** Known precursors and products are linked, and a series of links can reveal pathways (Panel 3).

The information-seeking mantra is applied in Fig. 7.5 as:

- **Overview** of all bimolecular interactions in a patient (Panel 1.1).
- **Zoom** in on a particular biomolecule for more **details** (Panel 2).
- **Filter** by weight threshold (Panel 1.2) and by disease pathway (Panel 3).
- **Relationships** between biomolecules are represented as lines and the increases/ decrease in quantity from the norm are mapped to a colour scale (Panel 1.1).

7.6 Evaluating Visualisations

Evaluating a data visualisation is an essential step in ensuring its value and testing its fit for purpose. Evaluation requires an iterative process, as opportunities to improve the design come through feedback collected using a range of *design thinking methods*. Two highly-regarded design thinking methods used to evaluate data visualisations are *Think Aloud* (Charters 2003; Tomitsch et al. 2021) and the *System Usability Scale*, or SUS (Lewis 2018; Tomitsch et al. 2021). Think Aloud studies collect qualitative data, while the SUS is a quantitative survey (for information on these and other evaluation methods, see Tomitsch et al. 2021).

Another approach, called a *Heuristic Evaluation*, uses predetermined principles (or heuristics) as guides for evaluating a design before it is given to users. This evaluation is done by someone with expertise in a relevant discipline (such as in design, data visualisation, or the pertinent data). Heuristic principles were initially developed to evaluate any piece of software, but heuristics specific to data visualisation have been developed (Dowding and Merrill 2018). These principles are:

- *Spatial organisation*—how easily information is positioned in the visualisation.
- *Information coding*—the appropriateness of symbols and representations used.
- *Orientation and help*—the ease with which the user can start using the visualisation.
- *Data set reduction*—the ability of the user to filter data.
- *Flexibility*—the ease with which users can control the data they see.
- *Consistency*—the reproducibility of the data visualisation across similar contexts.
- *Remove the extraneous*—the simplicity of data presentation.

In a heuristic evaluation, the expert uses the visualisation with some goal in mind and rates each heuristic on a scale from 0 (no issue with this principle) to 4 (catastrophic issues, which must be fixed). Violations of the principles should be identified in terms of their severity and urgency (Nielsen and Molich 1990).

As with Stasko's formula for value, the objective here is not to ensure that the principles are strictly followed but to identify trade-offs. For example, "remove the extraneous" suggests that a visualisation should use the least amount of ink (or fewest pixels) to show the greatest amount of data, but it is not a hard-and-fast rule (Bateman et al. 2010). Truly minimalist visualisations are confusing to readers because they are unfamiliar, while graphical embellishments catch the eye of a busy or distracted audience of non-experts (Inbar et al. 2007). There is always some trade-off to be made, and understanding the audience allows you to maintain balance with these principles.

7.7 Summary

Data visualisation requires an understanding of how we see, process, and respond to a presentation of data. Designing "good" visualisations, which are effective, valuable, and relevant, starts by understanding your audience, their level of expertise, and their context (or situation where they use your visualisation). Since all audiences are different, using an iterative process that considers feedback from user groups or experts in design is critical. There is no single visualisation that works for every data set, but following a user-centred approach, applying visual design principles, and taking time to evaluate your work is a pathway to good data visualisation.

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Decision-Making Models for Scientists

8

Rick Flowers and Franziska Trede

Abstract

Society is faced with complex and indeed wicked problems that cannot rely only on scientific solutions nor be solved by one scientific discipline alone. This is why scientists should not be positioned only as technical experts but also as decision makers. Scientists engage actively in various types of decision-making practices. We argue it is important that science students be exposed to collaborative decision-making with colleagues from diverse science disciplines and furthermore with non-scientists from diverse professional backgrounds. In this chapter we unpack decision-making by outlining three typologies:

- Structured and unstructured
- Top-down or autocratic, bottom-up or participatory, and consensus-based, and
- Decision-making in simple, complicated, complex, and chaotic contexts.

In all three typologies, scientists are involved in decision-making not only with other "experts" but also diverse stakeholders and persons in positions of authority. In the conclusion, we argue that the chances of solving wicked problems are increased by transdisciplinary and creative collaborative processes. This leads to decision-making that can be challenging but exciting.

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8.1 Defining Decision-Making

Let us start with the basics. What is decision-making? Howard Gardner (1993), well known for his analysis of the nature of emotional intelligence required for decision-making, asserts that decision-making starts with understanding the context and determining the need for and impact of a decision. Decision-making should be underpinned by research, information available, identifying choices, and acting on the appropriate choice. His emphasis on choice signposts that decision-making relies on multiple intelligences including knowledge, experience, and ethics; in short, professional judgment. Decisions are informed by analysis of a set of findings, situations, or problems. This chapter explores the roles scientists play in decision-making, and offers suggestions for incorporating this into teaching science students.

8.2 Normative, Contested, and High-Stake Decision Making

Managers and policymakers invoke scientific research when justifying their decisions. Often, scientific findings involve high stakes. Consequently, scientists are not merely passive bystanders or technical servants. They exercise authority, not so much because of their institutional position, but more by virtue of the respect the public has for their knowledge. And indeed, rational, scientific knowledge is typically seen as more important than practical, cultural, and experiential knowledge.

There is an adage "truth to power" which implies that scientific knowledge equates to "truth." A starting premise is that scientific findings are wide, if not universally, accepted benchmarks—in other words, norms—that shape decision-making practices. A normative perspective assumes that decision makers know of and adhere to these benchmarks/norms, and are thereby rational. A premise of this chapter, however, is that normative decision-making approaches should be contested. Even when presented with compelling "scientific" evidence, decision-making should take account of divergent viewpoints and irrational deliberations.

> Any (scientific) issue ... is not answerable by facts alone. This is because majority and minority values—culturally created, instituted and expressed ... differentially condition what facts are seen to matter and how. They also condition how the (scientific) 'problem' ... is perceived and what 'solutions' seem reasonable, affordable, effective, moral, fair or risky (Castree et al. 2021, p. 63).

Consequently, science-informed decision-making requires a significant amount of deliberation from diverse perspectives and interests (von Winterfeldt 2013). It may then seem that "scientifically informed" decision-making can be "paralysing when set against a backdrop of competing social, economic and political objectives" (Addison et al. 2013, p. 490) but with deliberate planning it is possible to facilitate agreements.

8.3 Structured and Consensus-Oriented Versus Unstructured and Expert-Led Decision-Making

A structured approach to decision-making carefully takes account of the various individuals and groups who have a stake in the decisions. This requires paying attention to the interests, knowledge, and views of all involved, no matter how contested these things may be. A structured approach seeks to systematically build consensus. To reach a consensus, it is necessary to deploy processes that enable each party to have their views heard, respected, and evaluated. That is why a structured approach to decision-making is important.

The structured approach may seem to align well with the systematic nature of scientists who are widely seen as advocates of experimental research. Scientists are experts and it is understandable that they want their specialist knowledge to be respected. It is tempting for scientists to not really care much about the views of other stakeholders because scientific knowledge is seen as the gold standard. As a consequence, in practice, we see scientists who prefer unstructured approaches, because they might assume that this protects their autonomy in decision-making. There is, indeed, a body of decision-making research with findings that confirm that often scientists deploy and indeed prefer unstructured decision-making. Prue Addison et al. (2013), for example, describe how science informed decisions "are often supported by unstructured subjective judgments, such as intuition, personal experience or unaided expert opinion" (p. 490). And the problem is that:

> Unstructured subjective judgements can lead to opaque, biased (even when they may be science-informed) decisions that rest on hidden assumptions and individual agendas (Burgman et al. 2011 in Addison et al. 2013, p. 490).

In his essay about bridging science and decision-making, Detlof von Winterfeldt asserts:

> Most decisions are made quickly, based on feelings, past experiences, associations, habits, trivial consequences, or obvious preferences (2013, p. 14056).

We think this comes about because, despite the idea that scientists are rational decision makers, they often make decisions without consulting policy makers, let alone grassroots and other stakeholders.

To illustrate the structured and unstructured approaches to decision-making, let us imagine a hypothetical example of planning how to manage a COVID virus outbreak. A structured approach would not only embrace the advice of health experts and policymakers but also include consultations with local community leaders, small and big businesses, sporting, arts, and cultural groups. These might be through surveys, interviews, meetings, and creative methods such as citizen juries. In an unstructured approach there would be few consultations—instead, the decision-making may rely heavily on the advice of a few, chosen, health experts.

8.4 Decision-Making in Groups and Types of Participants

Scientifically-generated knowledge is an important contributor to decision-making; but it is important for scientists to remember that process and people are also crucial for good decision-making. When making a decision, many types of participants should be at the table.

These people fall into several groups as defined by Addison et al. (2013) - "decision-makers (those with legal/regulatory right or responsibility for the decision), stakeholders (those involved in or affected by a decision) and experts (scientists and others with direct experience of knowledge of the problem at hand)" (p. 491). All of these types of people can have relevant expertise (defined as qualifications, track record, and respect) Burgman et al. (2011).

Structured processes to bring these people into the decision-making process are also essential. In the next part of this chapter we will describe and discuss three broad models of decision-making processes: top-down or autocratic; bottom-up or participatory; and consensus-based. We will then discuss a further typology drawn from Snowden and Boone's Cynefin framework (2007) that intersects with the three models.

8.5 Top-Down or Autocratic Group Decision-Making

There is a clear institutional and political hierarchy in top-down decision-making processes. In this model, a small number of people in positions of authority and/or a small group of experts decide. The potential advantage of this process is that it requires less time, and also few people, to make a decision. It can be efficient. Furthermore, a top-down or autocratic decision can be less ambiguous than a decision that has been made and reviewed by various committees and working parties. Another advantage is that experts and/or people in positions of authority often have the skills, inclination, and confidence to make decisions. The potential disadvantage, however, of top-down decision-making is that the content of decisions is narrow in scope and overlooks the insights and ideas of people who are directly experiencing, and being impacted by, the decisions and issues at hand.

8.6 Bottom-Up or Participatory Group Decision-Making

Top-down decision-making models are underpinned by the notion that knowledge of persons in positions of authority, or possibly the knowledge of "experts" is most important. In contrast, bottom-up or participatory models are underpinned by a perspective that most values the knowledge of frontline stakeholders, i.e., persons who are experiencing the impact of potential decisions (Flowers et al. 2009).

When it comes to making decisions, epistemology refers to a process of considering whose knowledge matters. When making a decision, it is always important to consider which knowledge matters most.

- Is it the knowledge of the people on power and authority? Is it the knowledge of the stakeholders, who are affected by the the decision? Or, is it the knowledge of the specialist and technically qualified experts?

For scientists who work hard to produce research findings, it may at first seem misplaced to say that stakeholders, and not experts' knowledge, should be highly valued. But in the context of science-informed decision-making, it should be noted that seeking to deploy a participatory approach does not mean the findings of scientists and experts are to be ignored. Instead, a participatory approach privileges how stakeholders *interpret* the findings. Their interpretation constitutes knowledge. Indeed, this is an advantage of bottom-up epistemologies; it taps into the lived knowledge and experiences of people directly impacted by the decisions at hand.

There are, however, substantial challenges to deploying a participatory decision-making model. In many cases, frontline stakeholders may be people without much formal education; who have few opportunities to exercise authority in their working, let alone private, lives; and who have low levels of self-efficacy. All this adds up to a potential situation where the stakeholders have little confidence or skill to contribute to decision-making. Furthermore, participatory decision-making is resource- and time-intensive.

8.7 Consensus Group Decision-Making

Bottom-up decision-making seeks to build "buy-in" from frontline stakeholders. Yet, like top-down decision-making models, it too can be contested. There can remain disagreement between those who are in authority, the grassroots participants, and experts. A third and alternative model is consensus group decision-making. In this model, the commitment is to name, and bring out into the open, divergent views. This requires carefully structured, long-term processes of facilitation to allow all parties to have their say in order to build consensus. The challenge of this approach is the time it takes for parties with divergent views to find positions and interpretations on which they can all agree. This approach requires time and a facilitator with the skills to create conditions in which people listen to each other. It also requires participants with patience, the willngness to compromise, and the ability to accept new perspectives.

8.8 Assumptions That Underpin Science-Informed Decision-Making

Three models of decision-making are outlined above. They beg a question: how do we decide which model to deploy? The answer depends on foundational assumptions about the nature of the problem being addressed. If we assume the problem can be clearly defined, a corollary assumption is that it is possible to decide on a single and optimum solution. In this case, a top-down decision-making model would likely be deployed because it is seen as most efficient. But if we assume the problem cannot be well defined, either a bottom-up or a consensus model of decision-making is more likely to be deployed. The former is sometimes labelled as a hard-systems approach, and the latter as a soft-systems approach. We prefer, however, to see intersections between top-down, bottom-up, and consensus decision-making models with four domains of decision-making as described in the Cynefin framework.

8.9 The Cynefin Framework

Snowden and Boone (2007) created the Cynefin conceptual typology to aid decision-making practices of managers and leaders. They assert it is helpful to conceive how different types of problems are best solved by different types of decision-making.

> We believe the time has come to broaden the traditional approach to leadership and decision-making and form a new perspective based on complexity science. Over the past ten years, we have applied the principles of that science to governments and a broad range of industries. Working with other contributors, we developed the Cynefin framework, which allows executives to see things from new viewpoints, assimilate complex concepts, and address real-world problems and opportunities. (*Cynefin*, pronounced ku-*nev*-in, is a Welsh word that signifies the multiple factors in our environment and our experience that influence us in ways we can never understand) (2007, p. 1).

The typology includes four decision-making domains:

- Clear (Berger and Johnston, 2015).
- Complicated
- Complex
- Chaotic

8.10 Domain 1: Clear Contexts and Decision-Making

In this domain, it is assumed that the problem at hand can be defined with clear cause-and-effect relationships. Further, it assumes there is widespread agreement about the decisions required and a perception that there is little need for analysis, research and consultation. Decision-makers:

> . . . sense, categorise, and respond. That is, they assess the facts of the situation, categorise them, and then base their response on established practice (Snowden and Boone 2007, p. 4).

This framing of simple decision-making has obvious similarities to top-down or autocratic decision-making models. The important contribution of the Cynefin framework is that it deepens insights into advantages and challenges of various types of decision-making practices. In this case, simple, linear, and top-down decision-making runs the risk of underestimating the nature of the problem at hand. If it is indeed more complicated or complex than perceived, the planned solutions are likely to only partially solve the problem. Another potential shortcoming is, because it is assumed that a small group of decision-makers—be they experts or people in positions of authority—know the right answer, the ideas and knowledge of a wider circle of people are not heeded.

8.11 Domain 2: Complicated Contexts and Decision-Making

Domain 2 assumes that the situations surrounding problems are ever-shifting and multifaceted and so the relationship between cause and effect is not clear. While decision-makers "in a simple context must sense, categorise and respond to a situation, those in a complicated context must sense, *analyse* and respond (their emphasis)" (Snowden and Boone 2007, p. 6).

Complicated problems call for a wide circle of knowledge to generate various possible solutions. This type of decision-making resonates with both, or sits between, top-down and participatory decision-making models. It calls for casting the net wider than in traditional top-down decision-making models, but still relies heavily on the knowledge of people who are perceived as experts. And therefore, "innovative suggestions by non-experts may be overlooked or dismissed, resulting in lost opportunities" (Snowden and Boone 2007, p. 6). A polluted waterway can be seen as a complicated problem because there could be various causes, requiring potentially different types of expertise, and a range of possible solutions. Nonetheless, the number of possible causes and scale of possible interventions are probably limited.

8.12 Domain 3: Complex Contexts and Decision-Making

In this domain, the context is perceived as even more fluid and multifaceted than for complicated decision-making. Climate change is an example of a complex problem. There are myriad causal factors behind climate change. To illustrate, at a global scale evidence points to increased frequency of extreme weather events, glacial melting, rising ocean levels, more rapidly changing pressures from pathogens, pests, and weeds. They are high-order problems and more than complicated, they are complex. It should be noted that there is not a clear-cut difference between complicated and complex; it is more like a sliding scale with no clear boundary.

A burgeoning body of scholarship has arisen around the notion of complexity science or complexity thinking. To adopt a complexity science perspective requires an open mind, like explorers discovering previously unknown fauna, flora, and people in a new territory. These explorer-scientists cannot rely on an existing corpus of knowledge, let alone their particular disciplinary expertise, they must generate new knowledge and look to a wide variety of disciplinary expertise. Translated into decision-making practice, it means inviting, or at least allowing input from all types of stakeholders, experts, and people in authority.

> In this domain, we can understand why things happen only in retrospect. Instructive patterns, however, can emerge if the (decision-maker) conducts experiments that are safe to fail. That is why, instead of attempting to impose a course of action, (decision-makers) must patiently allow the path forward to reveal itself. They need to *probe* first, then sense, and then respond' (our emphasis) (Snowden and Boone 2007, p. 8).

This experimental style of decision-making goes against the grain not only of top-down, but also of consensus, and bottom-up, decision-making. While these three decision-making models strive to achieve agreements, decision-making in the complex domain is not pre-empted to allow patterns to emerge. This is described by some as akin to edge-of-chaos decision-making (Innes et al. 2005; Turner and Baker 2019).

8.13 Domain 4: Chaotic Contexts and Decision-Making

There are problems and situations where it is impossible to recognize any causes and effects. In such chaotic contexts, decision-making practice can only seek to manage crises. Here, decision makers *act* first, sense and respond.

8.14 Wicked Problems That Require Transdisciplinary and Creative Decision-Making

It is relatively easy to deploy decision-making for problems in simple and complicated contexts. One of the reasons that decision-making in complex contexts can be more challenging is because the problems being addressed have a myriad of cause-and-effect relationships. Rittel and Weber, design theorists, coined the concept "wicked problem" (1973). Such problems arise from multiple and conflicting goals; thus, one solution might solve part of the problem but cause other problems as a result.

Wicked problems require more than autocratic, participatory, and consensus decision-making. They require experimental forms of decision-making to befit their complex contexts. In practice, this can be facilitated by bringing diverse people together, especially those with diverse disciplinary types of expertise. For example, if marine biologists only collaborated with other marine biologists, they would probably make a particular type of decision. The decisions they make are likely to be different if they collaborate with plant biologists, chemical engineers, or industrial designers. Aslan et al., in making the case for inter- and trans-disciplinary decision-making, say:

> [by] breaking down barriers between disciplines and surrounding oneself with unfamiliar people, concepts, and perspectives, one can expand base knowledge and experiences and increase the potential for new combinations of ideas (2014, p. 345).

The intention of such deliberate efforts to bring about new combinations of disciplinary expertise is to generate novel and creative ideas and solutions. Such efforts require a wide repertoire of structured decision-making skills.

8.15 Incorporating Decision-Making into Science Teaching

Below are some suggestions for ways to incorporate knowledge and/or practice of scientists in decision-making into science teaching:

1. When teaching science in the context of societal issues:
   a. Acknowledge the role of scientists as decision makers, not only as technical experts.
   b. Discuss the roles that both scientists and other groups (experts, stakeholders, and decision makers) play in decision-making.
2. When discussing science as "evidence" or interpreting experimental results:
   a. Recognize and challenge prevailing hierarchies of knowledge, especially where experiential knowledge is seen of lesser value than scientific knowledge.
   b. Acknowledge that scientists have biases that can lead to unstructured decision-making.
   c. Discuss how individual people and groups hold different values; consider how these influence what facts are seen to matter. Values also influence how a (scientific) "problem" is perceived and what "solutions" seem reasonable, affordable, effective, moral, fair, or risky (Castree et al. 2021, p. 63).
3. If teaching decision-making explicitly, provide a scenario or case study and:
   a. Ask students to identify which of the three types of structured group decision-making processes they would choose and why, i.e., top-down or autocratic, bottom-up or participatory, and consensus-based.
   b. Ask more advanced students to identify which Cynefin domain applies to the scenario or case study: clear, complicated, complex, or chaotic.
   c. Have students analyze the perspectives of the different groups involved in the decision-making.
   d. Have students role-play individuals or groups in the process of group decision-making.
   e. Combine science students with students from other disciplines in groups to role play decision making—this works well in interdisciplinary units of study.

   See "Further reading/resources" below for helpful tools and case studies. Case studies linked with the UN's sustainable development goals (SDGs) also provide useful decision-making scenarios.

8.16 Useful Resources

At the end of this chapter, we have listed further useful resources. There is a blog written by Runge et al. (2020) that introduces their edited book that is organized around six decision types.

There is a short guide about consensus decision-making prepared by Seeds for Change. This is an NGO that provides training and support for campaign groups.

There is a facilitator guide of 60 pages by Sam Kaner with case studies and descriptions of practical skills and tools required when deploying participatory decision-making.

Simple Habits for Complex Times is a book by Berger and Johnston (2015). This book provides an overview of practical approaches to deploying complexity thinking for leadership and decision-making in large organizations.

The last resource is a journal paper by Pohl et al. (2017) that is useful because it presents examples of typical wicked problems and thereby illustrating how to scope a wicked problem.

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Communicating Science in a Space of Conflict

9

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Abstract

Science is integral to many complex and controversial issues. Concurrent with the advent of smart phones, the world wide web and social media, society is increasingly polarized politically and socially. Not surprisingly then, discussions about science can create spaces of conflict. This chapter looks at best practices in facilitation and building trust in the classroom, giving faculty the tools needed to teach and facilitate an understanding of science. These techniques can also be used to teach students to tell their stories and—most importantly—to appreciate and learn from the stories of others.

9.1 The Difficulty with Communicating Science

I remember in the 1960s and 1970s, the exhibitions in most museums/zoos/aquaria were focused on the "Wow!" factor. The *Tyrannosaurus rex* with its teeth bared; the "killer whale" jumping 40 ft in the air and splashing down throwing a torrent of water on the audience; "The largest diamond in the world!". All these fascinating objects, plants, and animals amazed and excited some of us to become scientists and teachers, but many people just went for the novelty of seeing these spectacles—it was entertainment.

Now, however, we are dealing with sensitive topics like pollution, food security, and species extinction. These issues are confronting and confusing. They generate conflicted feelings in an audience. As educators and communicators of science, it is no longer good enough (or effective) to just show an audience a "wow" item.

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Instead, we need to carefully consider how we communicate so we engage our audience more deeply.

In addition to the modern world being confusing and confronting, it is also opaque. The first day of my Digital Technologies class I give a student in the room a clear incandescent light bulb and ask, "How does this work?". They can say that the electricity comes in, and then flows through the filament, lighting it up, then down the other wire. And that is basically right! Then I plop my iPhone on the desk, "How does this work?". Blank stare. When I was growing up, if the TV stopped working, we opened the back and changed the tube. If the dryer stopped, we replaced the belt. We could change the tires, the oil and sparkplugs on our cars.

Today, our cars, phones, computers, televisions, and the internet, are so complicated. Most people have no idea how these technologies work, although we all rely on them every day. We also read science and technology headlines that make us uneasy. Amazon and Google use our personal information for advertisers' profitmaking. Credit card servers are hacked, releasing thousands of users' information. A new virus emerges, and there are rumors that it escaped from a science laboratory. Some people get sick from a vaccine, and citizens take to the streets in protest. It is no wonder that many do not trust science.

What do we do to help our students, and our other audiences, engage with science in the face of disagreement, misinformation, and discomfort? For a start, we need them to understand the process of science; how science is done. We also need to sit above the scientific process, and consider human tribalism, which has an enormous impact on the information people are willing to believe. And finally, we need to consider the best practices for communicating in a space of conflict.

9.2 Understanding the Process of Science: Learn by Doing

The principle of learning by doing has been used in education for thousands of years (Reese, 2011). Science education is no exception—sometimes the next path to understanding the scientific process is to give people the tools to figure it out for themselves. The following is one example from my working life, where non-scientists learned about evolution while playing in the dirt.

In the late 1990s, researchers at the Paleontological Research Institution, Cornell University, in Ithaca, New York, received a phone call from someone who claimed to have found a large bone in their backyard. This type of phone call is not unusual, as many people get excited at the thought of a dinosaur in their garden. The researchers were polite, asking what the bone looked like ("a femur"), and then asked about the dimensions; "it's about 4½ feet tall…". Ah! That is different.

The result of the dig was a beautiful, 10,000-year-old Mastodon skeleton; at the time, it was the most complete skeleton ever found. But the most important part of the dig was not the bones, but the matrix—the dirt from around the bones—that gave the real story of what New York State was like some 10,000 years ago. From the matrix, we could see a myriad of species of bivalves. Many looked similar to (but not quite the same as) the organisms we have now. The matrix gave evidence about species that are now gone from our area—dire wolves, ancient molluscs, and mammoths.

We started a Citizen Science project with the matrix, and took samples to schools, camps, and festivals. It was so much fun to see children--and adults--get that “Ah ha!” moment when they compared the tooth from the dire wolf in their hand to that of the wild coyote and fox we have today and realized that there has been “change over time.” Sound familiar? I never had to say the word “Evolution.” They *saw it for themselves*, and they owned the knowledge. They used the process of science to attain the meaning of evolution. As well, the project allowed us to circumvent the stigma some have against the word “evolution” by talking about change over time. Sometimes the best way to facilitate learning is to get back to basics and let people find information and ideas for themselves.

Citizen Science projects are a wonderful way to get students involved in the process of science; a well-designed project could also involve your students working with the community to help spread an understanding of the scientific process. There are many repositories for citizen science; for the Mastodon Matrix Project, we used one of the largest, SciStarter.com. Internet searches for citizen science projects also reveal some interesting opportunities. A few of my students’ favorites are AAVSO (American Association of Variable Star Observers), BBC Stargazing Live, ARCS (Arenas for Co-operation through Citizen Science), BeeSpotter, Canberra Nature Map, and eBird. There is literally something for everyone, from transcribing 200-year-old ship logs or counting bird species in your city, to sifting through 10,000-year-old matrix from a mastodon found in someone’s backyard.

9.3 Understanding Through Listening: The Basis of Our Biases

Humans are a tribal species. When we are faced with making decisions on complex or confronting issues—climate change, food security, vaccination during a pandemic—we usually look to our tribe for answers and safety. As the world becomes more complex, we rely more on people we trust to tell us how the world works and what we should do. If we, as scientists and science educators, are to facilitate an understanding of science for our audience, the first thing we need to understand is understand their perspective.

Two perspective seekers I admire are Dr Rob Ross and Dr Don Hass, both from the Paleontological Research Institution (PRI) and its Museum of the Earth. I saw Rob and Don at work with audiences in Pennsylvania and upstate New York during a huge boom in hydraulic fracturing for natural gas in the region. Residents and other stakeholders in the area were tense. Don and Rob organized town halls at the museum, and also visited colleges, high schools, and community centers to talk and, moreover, to listen.

They are both expert facilitators; they would introduce themselves, say a few things about what they do, then they listened for, what I thought, was an incredibly long time. With their calm demeanours, *their lack of jargon*, their *acknowledgment of the audiences’ fears*, and their *validation of people’s concerns*, Rob and Don would (mostly) win folks over. After that they would get people to listen to how the shale in their area came to have this resource, how it could be extracted, and where it lay on the carbon footprint scale of options for energy transitions. They did not bring opinions, judgment, or a flashy presentation. Instead, they were calm, factual, approachable, and receptive. There was often lots of handshaking at the end. They were acting as facilitators of conversation.

A facilitator is a neutral person who helps a group of people to understand each other and work together better. This is different from a mediator, who attempts to have people involved in a conflict come to an agreement by getting each side to understand the commonalities and the rationale for the needs that each has. We need mediators, to be sure; but most of us in science education need to be better *facilitators*. Listening is powerful.

Most of us will encounter multiple events of students (or colleagues) disagreeing, arguing, and if we are lucky, coming to some form of consensus, or agree to disagree. This is what we want; this is part of the process of science, too. As educators, we can also use facilitation techniques to help our students express opinions and explore ideas. A good facilitator can teach students that everyone can and should have a voice, as long as we are civil, respectful and kind to each other. When we learn to be good facilitators as faculty, our students learn from our actions—they learn to listen, respect and understand each other.

Ironically, much of our formal education in science involves learning to talk and write well. We do not learn so much about listening. Over the last 5 years, however, there has been significant increase in the number of professional development programs for active listening techniques. There are many that I have used in the classroom, including the LARA technique (Jonesburg, 2017), Tips on Facilitating Effective Group Discussion (Brown University), and Creating Safe Places and Brave Places (Vogel, 2020).

Below is my (and others') take on 20 years of facilitation in the classroom and in public. I hope it provides a jumping off point for you to develop your own techniques to share with your colleagues and your students.

9.4 Best Practices for Facilitation

1. *Know What Your Triggers Are*

Understanding what can trigger anger, frustration, or self-doubt as a teacher is important, and for many educators, this can be difficult. If you do find yourself being triggered in the classroom, here are some reflective questions you can consider:

- What "buttons" do I have that a student could push to induce emotion?
- What happens just before I am triggered?
- How do I feel in the midst of a triggering event, or afterwards?
- Am I making any assumptions about my audience that are unhelpful?

- How might my perceptions or my audience's perceptions affect the situation affect this situation?
- Is there someone I can bounce some ideas off, so I can cope with difficult situations more productively?

These questions are simple, but a quick "check in" with yourself or with someone you trust and admire can go a long way to addressing tensions in your teaching.

2. *Know Your Audience*

It is important to know who your students are and where they are coming from, but this can also be difficult to achieve. There are many strategies for getting your students to talk to each other and to you. You can start with simple questions where everyone can contribute, like:

- Where do you come from?
- Why are you taking this course?
- What past experiences have you had, if any, with the content of the class?

A "Think/Pair/Share" is an excellent conversation tool that is not too confronting for a class. Give the students a prompt and ask them to think about it for a short time. Then, ask then to turn to a nearby person (their "pair") and share their thoughts. If you want to know what they think, ask them to report their "pair" partner's opinion, or an idea they developed together. This allows them to express ideas without the fear of being personally "wrong."

In the Resources section I have cited the University of California, Berkeley, Center for Teaching & Learning, and Council on Science and Technology, (2012) for more ideas on specific Think/Pair/Share ideas, and other student-centered teaching methods. These references have a plethora of examples of how to get students talking about themselves and their class content.

3. *Before Facilitation*

Set Ground Rules

- This does not have to be a formal document, just give a couple of reminders to the students; for example "all comments are to be respectful, and on topic". Better still, ask the students to work with you to write the rules. Developing boundaries are important. *Getting everyone to agree to and abide by the ground rules can save you when things get tense.*

Process and Content

- Consider the structure of the conversation you intend to have. What framework will you use? How will you explain the framework to the students? How will you keep them orientated throughout the process as you progress through the discussion?

- Consider what thoughts, ideas, and emotions are likely to come up during the class. Plan time to acknowledge these during and at the end of the discussion.

4. *During Facilitation*

Voices

- Notice who is talking, who is perhaps dominating the conversation; do you need to intervene? Ask, “Have others here had this experience, or something like it?” “Can you help us understand?”
- Body Language can be one of the most revealing metrics in a discussion. Are participants “bound,” or “tight” (legs and arms crossed, looking at the floor, frowning), are they rolling their eyes, speaking a bit too loud? *If you look and sound calm, that can go a long way towards keeping others calm.*

Keep the Discussion Moving with Open-Ended Questions

- Open-Ended Questions are your friends. Avoid “yes/no” questions to your students. Instead, ask open-ended questions like “Can you tell me a little more about that?”, “How do others feel about this?” These questions (and the students’ answers) allow people to understand what is and what is not the problem, as well as helping to keep the conversation moving.
- Repeat what someone has said *in their words,* not your words. This demonstrates that you are listening and understand the speaker. It also helps to avoid misunderstandings.
- Admit when you do not know. Say “I don’t know much about that; does anyone else know?” Sending a question back to the group often yields a great answer from the students and gives them the opportunity to “teach the teacher” and each other.
- Be ready for conflict. This can be the hardest task in facilitation. Allowing space for opinions and keeping civil discourse is paramount. It can be helpful to repeat people’s words back to them so they know they are being heard, but also to factually point out what they just said. Remind people of the Ground Rules that you set at the beginning of the process (Vogel, 2020).
- It is OK to fail. It happens in teaching, it happens in facilitation, and as you get more experience it does get easier. However, we are humans, and sometimes no matter what the facts are, some people will never agree with each other.
- Do a quick evaluation at the end of the class with your students. Ask for their opinions of the session. You can do it in real time, but you will get more honest responses from an anonymous questionnaire. You can run an anonymous “one-minute paper” where students answer three critical questions:
  - “What worked for you today?”
  - “What didn’t work for you today?”
  - “Is there anything you would like to follow up with?”
- Take notes after every session. Do it right after the class, if possible. Feelings, words, and issues all fade fast.

- Drake and Battaglia (2014) describe these methods and provide a list of references to support the efficacy of the approaches.

9.5 Conclusion

In her book, *Common Ground on Hostile Turf* (Moore, 2013), Lucy Moore explains that mediation can provide a safe place for people to discuss their understandings, feelings, and fears. I believe good facilitation in the classroom works in this way too; it allows students to tell their stories and talk about their cultures. It helps them feel comfortable and valued in the classroom. Every one of my syllabi states that students, faculty, and teaching assistant will keep an open mind, give *all* the benefit of the doubt, and be respectful with their comments. Because I teach some very controversial subjects in my courses (cannabis, energy transitions, genetically modified organisms), I know I will encounter spaces of conflict in my classes. To reduce the potential for conflict I start every course by understanding people's backgrounds (their tribe). I also make sure they get to do hands-on science so they can make their own discoveries (rather than being told). And finally, I teach them how to facilitate a conversation to get to know the stories of others—which may be the most important lesson any of us can give.

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10 The Truth Force Instinct: Misinformation and How to Respond

Will J. Grant, Matthew S. Nurse, and Joan Leach

Abstract

It is a common desire of scientists, once they begin communicating publicly about their work or science more broadly, to correct misinformation.

This chapter provides a framework for thinking about this task. First, we provide an exploration of how and why misinformation spreads, looking at the problem from a range of scholarly lenses. We then propose a diagnostic frame for thinking about when misinformation matters and when it does not. Finally, we propose strategic and tactical steps that can be taken in cases where it does matter.

10.1 Introduction

In late December 2019, 25-year-old Connor Reed had been living in the Chinese city of Wuhan for three years teaching English. But, like many in that city at that time, he developed a bad cough and struggled to breathe. Though he was quickly hospitalised by the Chinese authorities, things soon got pretty bad. As Reed told *The Sun* newspaper later, "I thought I was going to die" (Pisa 2020).

As you might be guessing, Reed was one of the earliest people—in fact the first UK citizen—to be diagnosed with the disease we have come to know as Covid-19.

But—and here is where his story gets interesting—Reed did not want to do what his doctors instructed, and he refused to take their antibiotics. Instead, he used an inhaler and "drank a hot whisky with honey until that ran out" (Pisa 2020). "It's an old-fashioned remedy but it seemed to do the trick", he told *The Sun*. After two

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weeks in hospital he was discharged, only learning later he had had the disease that would go on to kill millions. "I am proof", he declared, that "coronavirus can be beaten".

Reed's story went viral. In a world desperate for information and safety, his home remedy was translated into dozens of languages and passed from person to person millions of times.

There were consequences.

Nasser Karimi and Jon Gambrell (2020) reported the story in the *New York Daily News*:

> Standing over the still body of an intubated 5-year-old boy wearing nothing but a plastic diaper, an Iranian health care worker in a hazmat suit and mask begged the public for just one thing: Stop drinking industrial alcohol over fears about the new coronavirus.
>
> The boy, now blind after his parents gave him toxic methanol in the mistaken belief it protects against the virus, is just one of hundreds of victims of an epidemic inside the pandemic now gripping Iran.

At that point, at least 300 people had been killed after drinking poorly-made industrial alcohol in an effort to ward off the coronavirus. Karimi and Gambrell pointed to the viral spread of Connor Reed's home remedy as contributing directly to the problem.

* * *

On February 15—a month before Covid-19 would be declared a pandemic—WHO Director-General Tedros Adhanom Ghebreyesus announced, "we're not just fighting an epidemic; we're fighting an infodemic" (Zarocostas 2020).

Combating misinformation has been a core challenge for scientists and science communicators for perhaps as long as there has been science worth communicating. This chapter explores this problem and what can be done about it.

10.2 The Problem of Misinformation

We can define misinformation as false or inaccurate information processed as if it is valid (see Lewandowsky et al. 2012). Misinformation differs from ignorance, which can be considered an *absence* of relevant knowledge (Lewandowsky et al. 2012). As will be explored below, misinformation also includes the subcategory of disinformation: false information that is intentionally misleading and deliberately shared (Struckwicke and Grant 2020).

10.3 A Long History

Though we might live in an era rife with fake news, conspiracy theories (Argentino 2020) and state-sponsored (dis)information operations (Linvill et al. 2019), misinformation is far from a new phenomenon. As Darnton notes, sixth-century Byzantine historian Procopius "churned out dubious information, known as *Anecdota* ... in order to smear the reputation of the Emperor Justinian" (Darnton 2017). During the Black Death in the fourteenth century, misinformation targeted Europe's Jewish population, leading to the worst anti-Semitic pogroms prior to the twentieth century (Cohn 2007). During the Spanish Flu pandemic, President Woodrow Wilson's Committee of Public Information declared "truth and falsehood" to be "arbitrary terms". This set the scene for a denial of the disease itself, with Chicago's director of public health remaining silent on the pandemic, arguing that "worry kills more than the disease" (Barry 2009).[1]

Other examples can be found in perhaps every century humans have written information down; if we could go back in time, we would probably hear our ancient pre-literate ancestors spreading misinformation then, too.

Nevertheless, it is possible to argue that we live in a time particularly ripe for the flow of misinformation. Recent political events, such as the 2016 US Election, Brexit, the 6 January 2021 insurrection at the US Capitol, the hyperviral spread of conspiracy theories like the QAnon movement and the infodemic noted by WHO Director-General Ghebreyesus suggest something different is going on.

10.4 Different Lenses

So how can we understand the problem of misinformation? Researchers have attacked the problem from a range of different directions, and it is likely that only a combination of perspectives will allow any headway on the problem.

Firstly, some have sought to understand the problem as a psychological one; as a fact or flaw of our cognitive make up. For example Lewandowsky et al. consider the cognitive factors that underpin misinformation acceptance and sharing, including "how people assess the truth of statements", "what makes people believe certain things and not others", and "people's memory for misinformation" (Lewandowsky et al. 2012).

The next lens is sociological, exploring the conditions between people—or in societies more broadly—in which misinformation spreads. In this, researchers might

[1] Meanwhile, the era represents perhaps a golden era for traditional forms of misinformational snake oil, with countless charlatans diving in with fake cures. These include the wonderfully named "Dr. Pierce's Pleasant Pellets", "Dr. Bell's Pine Tar Honey", "Schenck's Mandrake Pills", "Beecham's Pills" and "Miller's Antiseptic Snake Oil" (Zeitz 2020). Meanwhile Professor Bordier of the faculty of medicine at the Université de Lyon, France, claimed to have invented a cold-curing apparatus, which used tiny heat conducting plates attached to the nose, to supposedly kills the germs causing the cold. Perhaps the most dangerous piece of misinformation during the pandemic was the recommendation (including by the US Surgeon General and the Journal of the American Medical Association) that those suffering from the Spanish Flu take what is now known to be toxic dosages of aspirin, perhaps enough to cause some of the deaths (Starko 2009).

look at demographic variables, levels of social integration, community power structures or economic systems.[2]

Others have built on this approach to explore how institutions of governance and the media have fostered or hindered an environment conducive to misinformation (see for example Ognyanova et al. 2020).

Paralleling this, a range of other researchers have explored misinformation via a technological lens, looking at how technologies of communication—from printing presses (see for example Fernie 1993) through to broadcast TV, radio[3] and social media (Linvill et al. 2019; Hunt and Gentzkow 2017)—have contributed to the spread of misinformation, and how regulation might respond.

Finally, another group has looked at historical examples, finding direct parallels between our modern susceptibilities and instincts and those of our ancestors (see for example Barry 2009; Cohn 2007; Darnton 2017; Clamp 2020).[4]

In all, the key questions to address include why we fall for misinformation and why we share it with other people.

10.5 Why Do We Believe?

Well, why do we fall for misinformation? From a wider perspective, this question is perhaps a little backwards. In some ways, we should be impressed that we do have systems of enquiry (seen in the best parts of the academic, judicial and journalistic worlds) that pull us towards more truthful appraisals of the world. Nevertheless, we can point to a few things that contribute to our human likelihood of falling for misinformation.

We can start with a simple explanation—we tend to do and believe things that the people we like do and believe. This "consensus heuristic" reinforces the connections we have with our social circle, and is universal. From the community-building perspective, this is good! But it also means we tend to be biased towards the information coming from people we like—whether that information is valid or not.

Building on this, information consistent with our pre-existing worldview is, as Lewandowsky et al. note, "more familiar, easier to process, more coherent, more supported in one's network, and more likely to be viewed as coming from a trusted source" and is more likely to be accepted, even if false (Lewandowsky et al. 2012). We will even use motivated reasoning to hold on to treasured but false beliefs (Kahan et al. 2017; Nurse and Grant 2019).

[2] See for example Martin (1989), on the sociology of anti-fluoridation activists, or Grinberg et al.'s examination of so-called "supersharers" on Twitter (2019).

[3] John R. Brinkley's masterful use of the new technology of broadcast radio to advertise his charlatan medicine (including the xenotransplantation of goat testicles into humans) has been wonderfully documented by the podcast Reply All (2017).

[4] Dishearteningly, their argument seems to be that though things were bad in the past, we have not attained some radically different modern immunity to misinformation.

10.6 Why Do We Share?

It is likely that at some point in our lives, all of us have shared things that are not true. The question is why.

We can break this discussion into two components, falsehoods shared deliberately and those shared inadvertently.

Falsehoods shared deliberately are, as noted above, disinformation.[5] A range of examples exist where people deliberately spread disinformation for strategic, financial or personal reasons. The Soviet Union (e.g. Andrew and Mitrokhin 2001) and Putin's Russia (e.g. Belton 2020) have both demonstrated a rich use of disinformation for strategic ends. Similarly, stock market manipulators abound, sharing disinformation for financial reasons.

So, let us turn to the other side—misinformation shared inadvertently. Ellen Cotter's investigation of urban legends provides an interesting insight.

In her study, participants read a number of urban legends, and then rated how scary, believable and likely they were to share each article (Cotter 2008). Believability made people more likely to share. But so too did emotional response. Indeed, as others have shown, emotional arousal directly increases our likelihood of sharing information (Berger 2011). We often share things because they are emotionally arousing—making us happy or angry, or feel more secure or more alarmed (Tellis et al. 2019).

Beyond the information and its effect on us, we also share for the validation that sharing gives us in our networks. Here the support we get (either via social media "Likes" or the smiles and nods of approval of our listening audience) sets up a scenario where emotionally arousing content is more likely to be shared.

At this point, it should also be recognised that social media has made misinformation so much easier to share. It is perhaps this fact—rather than any mass decline in credulity—which has made this era a potential golden age for misinformation.

10.7 What to Do About It

In August 2018—days after US President Trump announced a new branch of the military in Space Force—science communicator/astrophysicist Neil deGrasse Tyson tweeted, "I'm okay with a US Space Force. But what we need most is a Truth Force — one that defends against all enemies of accurate information, both foreign & domestic" (Tyson 2018).

For his fans, this was right on the money; it has been liked over 167 thousand times. Instinctively, it feels right. A sensible, scientific approach to the problem. But is it? Is a "Truth Force" the right way to approach misinformation?

[5] Of course, once believed as real and shared as if real, disinformation becomes misinformation.

10.7.1 Diagnosing Whether to Respond

Well... not always. The first question we should always ask when encountering misinformation is whether to do anything about it at all. So, what should make up this diagnostic frame?

Firstly, not all misinformation is worthy of our attention. Many have pointed out the dangers of giving harmful fringe issues more attention than they deserve simply by trying to critique their factual basis. Is only one person tweeting about it? Perhaps they can just be left alone.

Secondly, we should think about the potential harms of any false claim, before we try to debunk it. In this, not all misinformation is inherently harmful. Astrology, for example is relatively harmless. Ideas that drinking industrial alcohol can cure Covid-19 can be very harmful.

But thirdly, we should also think about context—the alcohol story was particularly devastating when shared in a country where unregulated black markets are the only means of attaining alcohol. But was the story as dangerous in the other countries, where a hot toddy is probably more likely just to give a little comfort?

10.7.2 Strategic and Tactical Steps Forward

So if misinformation is worth responding to, what do we do?

First, we should recognise it is not an easy task. Misinformation can be sticky; refutations can occasionally lead to people entrenching their views (Nyhan et al. 2020); others speak of a “bullshit asymmetry principle”, which holds that the amount of information needed to refute bullshit is an order of magnitude greater than to produce it (Brandolini 2013). Topics of science are also often publicly controversial topics of politics too. When people discuss things like climate change, genetically modified organisms and vaccinations, many are not as interested in scientific findings as they are in standing up for their political or social tribes (Kahan et al. 2017; Nurse and Grant 2019). Combatting misinformation in this context means combatting a wider worldview than just one fact.

If we are to have an impact, recent research has shown that debunking work is more likely to be successful if it comes from a trusted source, not necessarily from someone with expertise (Ecker and Antonio 2021). This means that we should not rely on our qualifications or publications when trying to change minds. Instead, we should attempt to build more personal connections with audiences, finding common ground to show why they should trust us, or work with trusted intermediaries to bridge the gap.

Finally, it is worth noting that some are exploring ways to prevent people from believing misinformation in the first place. Prebunking and inoculation are useful techniques where people are presented with debunked information before they have encountered it in the wild (Roozenbeek and van der Linden 2019).

10.8 Conclusion

One argument we have raised in this chapter is that misinformation is "normal": it has always been part of our communication ecosystem. That does not mean we always need to accept it, but we do have to pick our battles. Another key theme is that science information does not come by itself into the public sphere—it is integrated with personal narratives (Connor Reed's personal whisky and honey narrative), politics (political claims about the various success rates of national vaccines), and emotive and fabulous imagery designed to get our attention. The very things that can make for good communication of science are also those that help misinformation travel. Professional communicators of science typically follow an unwritten ethical code (Medvecky and Leach 2019) that keeps them from spreading misinformation. But a quick like or share on Facebook or Twitter can potentially help a false bit of information take flight. In that sense, we all have an ethical responsibility when we like and share.

But as for a "Truth Force"? There is reason to believe that this approach will not work. Ask any climate scientist—facts and refutations are not great at changing people's attitudes and can back fire. That does not mean there are not times when calling out nonsense is not the right thing to do. We can increase the likelihood of success with strong systems of science communication where misinformation just stands out as wrong. So perhaps instead of a "Truth Force" we might be better working on a "Trust Force"—listening to people and understanding their motives, their place in a social system, and asking and giving reasons for defending certain scientific claims, however they come packaged.

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Further Reading/Resources

Beyond the sources directly cited in this chapter, you might also like to listen to *The Wholesome Show* podcast episodes 'Documenting the Infodemic' (https://soundcloud.com/wholesomeshow/documenting-the-infodemic), and 'The Spanish Flu!' (https://soundcloud.com/wholesomeshow/the-spanish-flu).

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Communicating Risk and Uncertainty

11

Rod Lamberts

Abstract

This chapter presents a brief overview of some fundamental concepts in risk communication between technical experts and non-technical laypeople. It touches on core elements of risk and uncertainty when they are described, interpreted, and manipulated to persuade people to take specific actions. It focuses on what technical expert participants in risk communication enterprises can do to reflect on their own role in communication successes and failures. This material is punctuated with examples from the author's experience of risk communication activities around Australia and the Pacific region.

Topics covered include various ways we understand risk and prioritise "risky" decisions, the importance of context and of identifying and recognising our assumptions in risk communication efforts, the necessity of explicit communication goals, and the pervasive influence of values. The chapter concludes with two activities and suggestions for further reading.

Research into risk perception and communication has been going on for decades. The volume of work is far too large to cover in a single book chapter. This chapter is a "taste test" of some of the aspects of risk communication that I have found to be among the most common and enduring. It is coloured with examples that typify how personal, ambiguous, variable, and context-dependent our views on risk can be. These examples also reveal how close the relationship between risk communication and science communication can be (e.g. in climate change debates or public health deliberations). If nothing else, I hope a reader new to risk communication will come away with a clearer impression of the potential complexity inherent in risk communication exchanges, and a deeper

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appreciation of the extent to which "successful" risk communication is rarely about just explaining the data.

11.1 Risk, Uncertainty, and Hazard

In everyday life, using the terms "risk" and "uncertainty" interchangeably is acceptable. Both terms convey the impression that the behaviour, situation, or object being discussed has unknown elements that have some level of potential danger, threat, or loss.

From a technical perspective, however, the difference can be critical. This century-old economist's comparison of risk and uncertainty explains the distinction as well as any circulating today (DeGroot and Thurik 2018, pp. 1–2).

> In the case of risk, the outcome is unknown, but the probability distribution governing that outcome is known. Uncertainty, on the other hand, is characterised by both an unknown outcome and an unknown probability distribution. In both cases, preferences are defined across chance distributions of outcomes. For risk, these chances are taken to be objective, whereas for uncertainty, they are subjective.

In practice, everyday use of the term "risk" is likely referring to what scientists would call "uncertainty". That is, not only is the outcome unknown, so too is the probability of that outcome.

To calculate risk technically, the conceptual relationships represented in the following formula are beguilingly simple*: risk* = *probability x consequence*. Here "probability" is the likelihood of a hazard coming to pass, and "consequence" reflects how severe the effects of realising the hazard would be.

So, what is a "hazard"? If "risk" is the likelihood, or probability, of harm occurring should something happen, "hazard" refers to the object, situation, or behaviour itself. For example smoking cigarettes is a hazard, the *likelihood* of getting lung cancer as a result of smoking is the risk.

But, the term "hazard" expands when examining what happens when the technical expression of a risk meets alternative perceptions of risk in communication exchanges that include non-technical participants.

When risks are communicated in situations beyond the realm of technical domain experts, people's relationship with, and responses to, them almost always encompass more than objective calculations.

As Peter Sandman puts it, in these contexts: *risk* = *hazard* + *outrage* (Sandman 1989).

Here "hazard" now stands for both elements of the technical risk equation above, and "outrage" represents people's perceptions of, and reactions to, the hazard should it actually manifest. Outrage need not have any relationship to the technical realities of the risk being realised (Sandman 2003).

For the purposes of this brief introduction to elements of risk communication, unless the technical distinction between risk, uncertainty, and hazard is critical to appreciating a specific concept, the word “risk” will be used.

11.2 Assumptions, Goals, and Context

It makes little sense to get involved in risk communication without having a reason for doing so. The most common reasons I have heard people say they want to “do” risk communication are:

- To inform people or “raise awareness” of a risk,
- To persuade people to “do something” about a risk, and/or,
- To learn about a risk from others.

Regardless of motivation, all risk communication efforts will benefit from starting with an explicit examination of the assumptions that motivate the effort, the goals to be realised, and the context in which the efforts will operate.

For more than two decades, I have interacted with all manner of sciences and scientists. In almost every interaction, I am struck by how passionate these people are about their work and its value. In the context of risk communication, none are more fervent about this than climate scientists.

A composite example of many of my interactions with climate scientists offers a neat illustration of the importance of having clear appreciation of assumptions, goals, and the centrality of context in risk communication.

Composite climate scientist: *The public need to understand (more) climate science.*
Me: *OK, and why do you say that?*
Composite climate scientist: *Because the climate situation is looking really bleak, and we need people to do something about it!*

11.2.1 Assumptions

We all make assumptions every day, often unwittingly, and usually without profound consequences. However, in risk communication (which I approach as a branch of science communication), acting under the influence of unconscious assumptions can be problematic.

In the example above, the composite climate scientist assumes that people do not “do something” about climate change because they do not know enough about it. This is not to impugn the scientist: it is easy to appreciate why they would assume knowing more about the dire situation would motivate action. Unfortunately, we know that merely increasing science knowledge does not guarantee people will act (Simis et al. 2016).

But how can we identify our implicit risk communication assumptions? One simple strategy is to check our language for phrases like "people should really. . ." or "what everyone needs to know is. . .". Assertions like this can flag where we are making implicit assumptions about the effects our communication efforts will have. Once they are identified, they can be verified.

11.2.2 Goals

It is impossible to estimate the success or failure of a risk communication without first being clear about what you are aiming to do, and having ways to tell the extent to which you have done it. This is something that needs to be done explicitly if you want to be confident about the extent to which your communication efforts have succeeded.

Let us imagine here that communicating more climate science in fact does increase climate-positive behaviours. What exactly are these climate-positive behaviours, and how do we know if they have increased?

Goals such as "improving the climate" are noble, but ambiguous and seductive. It is easy to agree on such goals with like-minded people without exploring if they are realistic or measurable. Explicitly articulating goals and their indicators might not guarantee success, but it certainly helps clarify the task upfront and identify if there was any effect afterwards.

11.2.3 Context

There is an enormous number of potential context factors that affect risk communication efforts. Appreciating the context in which you, and the audiences with whom you are communicating, will engage over risk communication activities is critical to maximising your likelihood of success.

For example climate scientists know that phasing out coal is an essential part of climate change action. For them, phasing out coal as fast as possible is not just desirable, it is essential. But for people who rely on the coal industry for their income, the life-changing consequences of shutting down mining could represent a far greater, and more immediate threat. Risk communication enterprises need to be tailored to the contexts in which they will be conducted, and the most influential elements in one context may be of little concern in another.

11.3 Perspective Is Everything

In the early 2000s, a UNESCO science advisor told me a story about a dietician working in Samoa to help address their high incidences of obesity, diabetes, and heart disease. As in many countries around the world, whenever there is a celebration in Samoa, there is feasting. In this case, people were celebrating the opening of a new school. At the ceremony, there were tables covered in all manner of foods, including one that was stacked with cans of preserved meat. The canned meat had been a common staple in many Samoans' diets for decades. It was also very high in fat and salt—key contributors to the diseases the dietician was there to help address.

When the dietician suggested that these meats were harmful and should be cut back, one local asked if she was suggesting they give up a traditional food. The dietician was surprised! The meat had been introduced some decades before by Anglo visitors to the country: not something an outsider might have thought of as "traditional".

In this example, the risk the local saw (giving up on a traditional food) outweighed the risk the dietician saw (removing an unhealthy food). Both positions were legitimate from the individual's perspective, but the risk they saw was quite different. Years late I told this story in New Zealand, and afterwards a Samoan man told me that it was less about the canned meat being a traditional food as it was a filling, affordable meal addition that would not spoil in villages where there was no refrigeration. For him, removing canned meats meant people might go hungry or be in danger of eating spoiled food: much more immediate than the diseases of obesity, and now a third perspective on the risk issue.

In risk communication perspectives matter, though they may not be immediately obvious to the various parties involved. When investigating the potential impact of perspective, here are four key questions to consider:

1. Relevance—is this risk relevant to people's day-to-day lives, and if so, how (and how do you know)?
2. Pre-existing biases—do people in the intended audience already have a position on the risk, and if so, is this position (a) aligned with or opposed to our own, and (b) strongly held?
3. Threat to status quo—would becoming (more) aware of the risk we want to communicate unacceptably jeopardise or threaten audience members' existing beliefs, values, social systems, livelihoods, or lives?
4. Ability to act—even if they accept and want to mitigate the risk being communicated, do they have the time, knowledge and resources to do so, and what trade-offs are required?

11.4 Choosing Between Risks

It would be impossible to gather and weigh up the evidence behind about every choice we make each day. This is why we accept the instructions of doctors, mimic our friends, and watch the movies suggested by Netflix.

All of us unconsciously use shortcuts (or *heuristics*) daily when making choices between competing options. For example many of us make a decision every morning before we leave the house: we look at a weather forecast and decide whether to take rain protection or risk leaving it behind.

Usually, weather forecasts (or "rain risk communications") present the likelihood of rain as a percentage, such as "the chance of rain this morning is 25%". But what does that mean when making a practical decision? Do you hang your washing outside if there is a 25% chance of rain? What about at 35%, or 60%?

According to Gigerenzer et al. (2005), we are likely to pay less attention to what the specific percentage is, and choose depending on how close it is to one of three values: 0%, 50%, or 100%. A 0% prediction leaves us confident that it will not rain, but so does a 10% or 20% prediction. Similarly, 80 or 90 percent is close enough to 100 that we are likely to see the risks as roughly equivalent.

When the prediction is closer to 50%, it becomes harder to decide, and people are also more likely to think the forecasters do not know what they are talking about.

The mere presence of numbers can also affect our estimates about facts concerning our own lives, as this brief example of the phenomenon of anchoring and adjustment demonstrates (West and Meserve 2012). In this study, people were asked one of two questions: "How many headaches do you have a month—0,1,2—how many*?"* or "How many headaches do you have a month—5,10,15—how many?"

Estimates were routinely higher when the question prompt included larger numbers, even though those numbers were entirely arbitrary. This simple example elegantly reveals the importance of context on choice.

It is also common for people to judge how well a risk has been handled based on how well it turned out after the risk has passed, rather than what kind of information was available to the decision-maker at the time they were determining what to do. This is referred to as 'outcome bias', and I used to see this happen regularly when I worked as a security guard (aka a 'bouncer') at a large concert venue in my undergraduate days.

The head bouncer had to estimate how "risky" the evening would be, prioritising negating the risk of harm to concert-goers, band members, the building and the staff, and roster on people accordingly. For the manager of the venue, a core priority was profit, so he would always look to cut costs.

If a concert finished and there was no overt violence or damage, the security team thought it had been a good night: security risks had been successfully managed. But on those same nights, the venue manager would often complain that the head bouncer had put on too many staff. For him, the fact that nothing went wrong was evidence that the head bouncer had mismanaged the "real" risk: spending more than necessary. The manager thought the lack of trouble meant there was a superfluous security presence: classic outcome bias.

Next, we turn to a simple set of risk-decision dichotomies from Fischhoff et al. (1981). Here the authors summarise findings from many studies and practitioner experiences into simple pairings of risk preferences: in essence, a summary of shortcuts.

This summary reveals that in general we judge risks befalling children as worse than those affecting adults. We favour risks that are voluntary over those that are imposed upon us by others. Risks that are from familiar causes seem less threatening than those from exotic sources and those that have little or no benefit to us are judged as worse than those that have clear benefits.

It has been easy to see instances of Fischohff et al.'s dichotomies at play during the COVID pandemic. For example among people who prioritise "freedom of choice" above all, the perception they may be "forced" into having a covid vaccine involuntarily can render other facts about the vaccine irrelevant.

This example also provides an excellent case for demonstrating the "hazard plus outrage" interpretation of risk perception introduced earlier. Some among those who are resistant to having a COVID vaccination argue that the vaccine is unproven and could be dangerous. For them, the potential consequences of taking it represent an acceptably high level of personal risk. However, a number of these same people also express strong resentment at being told what to do by government authorities in many aspects of their lives.

From a "hazard plus outrage" perspective, their expressed outrage about the hazards of the vaccine may well be driven by their more strongly fuelled outrage at being compelled to take it. Here, the issue people are upset about (the threat of involuntary vaccination) and the hazard they overtly express outrage about (the possible dangers posed by the vaccine itself) are quite different.

The lesson here is that you cannot effectively engage in risk communication with people about the realities of a hazard (vaccine side effects) if you do not address their outrage (forced vaccination).

11.5 Values and Tribalism

No primer on communicating uncertainty and risk would be complete without noting the profound influence of shared values, sometimes called "tribalism", on how we appreciate and relate to risk perception and communication. Kahan and his colleagues refer to this as "cultural cognition of risk", which is grounded in "the tendency of individuals to form risk perceptions that are congenial to their values" (Kahan et al. 2011, p. 147).

This theory goes on to assert that humans "endorse whichever position reinforces their connection to others with whom they share important commitments" (Kahan 2010, p. 296). The implications of this for risk perception and communication can be profound.

Turning once more to the covid vaccine example, the depictions of iconic anti-vaccination, anti-authority, libertarian American citizens that flooded our screens throughout 2020 epitomise the cultural cognition of risk idea. Viewed through this theoretical lens, their anti-vaccination position can be characterised as one that reinforces the anti-authority values of their group. A cultural cognition of risk perspective enhances our capacity to make sense of their outrage.

11.6 What Next?

This chapter is really a snapshot of a summary of an overview of the myriad factors that may be at play when making sense of, and attempting to communicate, risk and uncertainty. As such, the material presented here should be seen as a launchpad from which interested readers can explore the enormous body of related scholarly and practice-oriented literature.

With this in mind, perhaps the most important message to takeaway for now is this: *the first step in successful risk communication starts with reflecting on your own position*.

Explicitly and honestly articulating your motivations and exploring your assumptions within a risk communication context should help identify potential complications and illuminate fruitful ways to move forward.

11.7 Activities

11.7.1 Activity One

Write 2 opinion pieces (500–1000 words) on a single, controversial, science-based topic about which you hold strong, partisan views (e.g. climate change, vaccination, GM crops, A.I, etc.). Piece one should align with your views, piece two should argue the opposite.

Purpose—to interrogate personal values and then actively consider why and how others might oppose them.

11.7.2 Activity Two

1. Choose one controversial, science-based risk topic.
2. Have everyone draw a mind-map of the issue and all its relevant aspects (see Morgan et al. 2002).
3. Compare yours with other people's.

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Part II

Practice Engaging

12 The Five-Box Talk Structure

Toss Gascoigne and Jenni Metcalfe

Engaging - Speaking - Organising

12.1 Learning Outcomes

After completing this exercise, students will have a structure for a presentation suitable for any audience, from research colleagues to funding bodies. The structure works for both short and long talks. It depends on the magical sentence: "there are three things I want to talk about today." Distilling the talk into three main speaking points helps speakers organize their content, and avoid common errors: talks that obscure the main point, are hard to follow, or try to cram in too much detail. We call it the "Five-Box Talk" (introduction plus conclusion plus three points = a Five-Box Talk).

12.2 Teaching Context

The Five Box structure is one component of our training workshops in Presentation Skills. It is a simple and familiar idea, a classic approach to telling stories—think Three Little Pigs, Goldilocks and the Three Bears—and works across all disciplines, at all levels and across different cultures (we have taught it in 25 different countries). It covers most occasions when researchers want to talk about their work. Teachers

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will find the basic concept easy to explain. It also pushes speakers to focus on the important points they want to make and provides a structure for organizing their ideas.

12.3 Overview of the Teaching Activity

The first part of this activity introduces students to the idea that a presentation is not the same as a research paper and examines the differences.

The workshop hinges on a Socratic approach. We pose questions to the learners and invite responses. Together, we develop the Five-box structure.

We first ask "How can we structure a talk to get around the limitations of a verbal presentation?" The solution is to structure the body of the presentation around three main points. Speakers should first announce the three points, then work through them in turn, then remind the audience of what they were in the summary.

We then ask "What are suitable headings for the three main points?" The group discusses possible headings for the three main sections of their talk (they may need suggestions to start them off). One option is Problem-Research-Findings. Another is Past-Present-Future.

Finally, we ask "What about the other parts of the Five-Box Talk, the introduction and the conclusion?" The instructor leads a discussion on what should be in an introduction and conclusion, and why these are the most important parts of a presentation.

Students then use the Five-box template to prepare a talk. We get all students to deliver a demonstration talk of 3 min to the whole class and video it. Putting theory into practice reinforces the learning and we strongly recommend it if time permits.

12.4 Runsheet and Lesson Plan

The following lesson plan is one part of our presentation skills workshop which normally runs over one day. The whole workshop has a comprehensive booklet on "Presenting Science," covering three aspects of giving a presentation: Content, Style, and Visuals. The booklet includes notes and examples on each of Content, Style, and Visuals, and is available for purchase from Econnect Communication (admin@econnect.com.au). The lesson plan outlined below focuses on how to structure the Content using a Five-Box talk.

Instructor does…	Students do…	Resources
Ask students the differences between a talk and a paper. List responses on whiteboard (1).	Respond with suggestions	 10 min
Ask students for suggestions on how to overcome these limitations (2).	Respond with suggestions	 10 min
Suggest idea of "there are three things I want to talk about today" Ask students "Why is three important? Why not four? Or five?" Talk about threes as a story-telling device. Invite students to nominate examples (3).	Respond with suggestions.	Rule of three resource (4) 10 min
Ask students: "If you were to talk about your research/project in three main points, what would they be?" Invite students to nominate possible headings (5) and whiteboard the responses.	Respond with suggestions	 15 min
Ask students to choose three headings to discuss their own work, and jot down the points they want to make under each heading. Remind students that soon (but not yet) each student will stand in front of the class and give talk of max three minutes. Facilitate discussion of everyone's three headings.	Write headings and dot points on ideas they want to discuss under each. Share ideas and offer feedback to each other.	 20 min

Instructor does…	Students do…	Resources
Explain that students now have three points, but this is a Five-Box Talk. Ask "What are the missing 2 parts?" Ask "What should be in an introduction?" Instructor whiteboards all responses, then consolidates them around the purposes of an Introduction (6)	Nominate an Introduction and a Conclusion. Make suggestions around what should be in these parts of a talk.	20 min
Ask "What should be in the conclusion?" Whiteboard the responses (7).	Respond through discussion	10 min
Discuss key aspects of the overall Five-box talk (8). Give students time to prepare their talks, using the Five-box template	Prepare three-minute talks	Five-box template sheet (9). 15+ min or overnight
With the group, watch each student's three-minute presentation and give feedback, focusing on content and structure. If possible, digitally record the talks and provide a copy to each student.	Present three-minute talks and give and get feedback.	Recording/filming device, microphone, tripod. Feedback sheet (10) 3 min per student
Total duration in-class = 120 min [+ time to watch students' presentations and provide feedback]		

Notes

(1) Some examples: papers have dense ideas, unlike a talk; papers can be read and re-read, a talk is often a one-off event; audiences lose concentration in a talk, so it needs to command attention.

(2) Some examples of triads in stories: Bible stories (Three Wise Men, Holy Trinity); fairytales like Goldilocks and the Three Bears; joke structures like "Three men walked into a pub" and the ensuing story.

(3) Here the instructor can add in other points if not covered by student responses (e.g., reduce the detail; repetition is important; simple slides with diagrams and pictures are helpful).
(4) Resource: https://en.wikipedia.org/wiki/Rule_of_three_(writing)
(5) You will probably need to give examples to promote discussion (e.g., Problem-Research-Findings; Past-Present-Future; Comparing three possible responses/solutions). It is important that these three sections are relevant to the audience.
(6) Introductions should: (i) get the audience's attention, perhaps with a personal anecdote; (ii) say why the audience should listen, explaining the significance of the talk; (iii) list the three points the speaker will cover. At this point, a brave instructor will give students a sample introduction, on a topic nominated by one of the students.
(7) Conclusions should: (i) echo the introduction; (ii) pose the rhetorical question "So what does all this mean? What are the implications of what I've discussed?"; (iii) be a reminder of the 3 points the speaker covered; (iv) have a strong exit line, which is the last thing the speaker says before finishing.
(8) Strong talks (i) include links between sections (example: Now that I have outlined the problem my work is addressing, let me turn to the second part of my talk: the research I am working on.); (ii) feature clear delineation between sections; (iii) include repetition that signposts where the talk is going and reminds the audience of the points.
(9) The Five-box template (Table 12.1) can be used by students to prepare their talk.
(10) The Feedback Sheet (Table 12.2) helps to provide written feedback to student presenters. It can also be used to stimulate a discussion in the group about what they did well and what they could do better next time.

Table 12.1 Five-box talk template

Introduction: • Get your audience's attention • Give them a reason to listen • Provide an outline of your talk
Link to the first point *Now let me turn to my first point exploring the problem of...*
Point 1: The problem my research is tackling
Link to the second point *Now that it is clear what the problem is, let me explain how my research tackled one aspect of that...*
Point 2: The research I am doing to tackle the problem
Link to the third point *Now that I have explained the problem and how we are tackling it, let me turn to our findings so far and how they are helping to solve this problem...*
Point 3: Findings of research and how tackling the problem
Link to the conclusion *So, in conclusion...*
Conclusion: • Summarize the talk • Remind your audience why your talk is relevant • Prepare a strong exit line

Table 12.2 Sample written presentation feedback to students

Evaluation	Feedback
Content	
Strong introduction	
Clear 3 points in the body of talk	
Sections of talk well linked together	
Compelling conclusion	
Relevant to target audience	
Style	
Eye contact	
Voice clarity	
Appropriate gestures/stance	
Visuals	
Clear and well designed	
Relevant to talk and audience	

12.5 Top Tips for New Instructors

1. This session is best run with small groups of about 10 people.
2. The sessions are not lectures, but discussions. We find participants get bored if they have to sit through lectures for an extended period. We seat participants in a hollow square, to promote discussion, and welcome questions and comments in audience participation.
3. If participants are reticent in responding we will ask them directly by name or use other approaches we have learned through experience. One approach is to announce a question and then say: "I'm going to get everyone in the back row for their ideas on this," and then go quickly along the line. This works well in larger groups if there is a hand-held microphone that participants can pass on.
4. Our sessions are practical in nature. We give examples and advice, discuss issues and then give plenty of opportunities for participants to put the theory into practice.
5. Some participants find public speaking a (traumatic) challenge, but you can use humor to lighten the atmosphere.
6. We recommend running sessions like this with a colleague, if possible. It provides instructor variety for the learners, and it makes the teaching less stressful. A technique that can work well is for instructor A to clarify publicly something with instructor B: "So when you said everyone has to give a talk, how long does it have to be? And what should they cover?" Having two presenters also means that while one instructor is filming participants the other can give feedback.
7. The 3-minute presentations are better if students have time to think about their talk; a coffee or overnight break works well.

Further Reading/Exercises

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Getting Students to Express an Opinion 13

Katherine O'Brien, Louise Kuchel, and Susan Rowland

Engaging - Conversation - Arguing

13.1 Learning Outcomes

After completing these exercises, students will be more comfortable giving an opinion, discussing, and questioning opinions, and considering the evidence they could use to back up or challenge an opinion.

13.2 Teaching Context

Science students have trouble expressing opinions. They worry they will be "wrong," or that they do not have enough evidence to irrefutably support their opinion. Sometimes scientists see opinions as valueless because opinions do not necessarily draw on all the facts. Even though opinions are not always "correct" (or fact-based) they can be great ways to start conversations and get ideas flowing in a discussion. Being able to express an opinion, explore it, and maybe even change an opinion without feeling ashamed or embarrassed, is a crucial workplace and social skill.

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We present three different exercises that ask students to express and examine their opinions without shame or stress. These exercises are all drawn from our classroom practice with science students and can be done in isolation or combined to help students develop opinions.

13.3 Exercise 1: Giving an Impromptu Opinion in a Conversation (Susan Rowland's Class)

13.3.1 Overview of the Teaching Activity

In this exercise, students are given stimulus data in the classroom. The information is used to spark an impromptu, opinionated conversation in the group where everyone's ideas are valid, and nobody is "wrong" or "right." The facilitator models, maintains, and encourages a respectful discourse so that all students can be heard. After completing this exercise, students will have experience giving and discussing an opinion in a supportive public forum.

This exercise is appropriate for any group of students but will work better with a small group (5–20 students) so everyone can participate. The exercise takes around 45 min; it will probably veer off course and go down some fun and interesting pathways.

As the facilitator, it is important to have a general "moral" or "learning" you would like students to achieve from the discussion. You can use any learning-relevant stimulus; the best stimulus is one where the students do not know much about the topic, and they cannot google "the right answer." Encourage students to draw on their own ideas and emotions for the discussion, rather than going to literature to get someone else's ideas on the subject.

In my class, I used data on the career outcomes for scientists (Table 2.1, Harris 2012). I wanted students to think about who they are as scientists, so thinking about career pathways for scientists was a useful way to approach this learning.

13.3.2 Runsheet and Lesson Plan

This outline is specific to my stimulus, but you can easily adapt it to your own.

Instructor does…	Students do…	Resources
Present the students with the table data from Harris (2012). Ask them to look at the jobs that scientists do and a) identify one job that surprised them then b) give one reason why the job surprised them	Read the prompt and formulate their answer	Harris (2012) (1.1) 2-5 min
Invite students to offer and explain their individual ideas to the class (1.2)	Respond and share ideas (1.3)	Supportive instructor 10 min
In response to thought-provoking student ideas, ask the class "What do you think? Who else was surprised by this? Why?"	Respond to instructor prompts and other students' opinions (1.4)	Whiteboard or other tool for mind-mapping 30 min
Return to the student/s who expressed the original opinion. Ask them about their opinion after the discussion	Original student responds	 5 min
Wrap up with reference to the desired learning. Ask students for "check-out" reflection on one new idea they had as a result of the discussion	Students share (aloud, in pairs, or in writing)	 5 min
Total duration in-class = 20-40 min		

Notes

(1.1) See References for Harris (2012).

(1.2) Remind students that this is an opinion and is their idea; nobody is testing to see if they are right.

(1.3) Some students give non-thoughtful responses. Acknowledge these ideas and constructively reframe them so they contribute to the learning you want your students to achieve. Thank the student. Continue asking for input until somebody says something thought-provoking.

(1.4) Be prepared for people to get quite interested. Maintain respectful discussions of people's opinions in the room. Thank each person for their contribution and consistently direct the conversation to productive avenues. Do not allow the original speaker to feel their opinion is being attacked.

13.4 Top Tips for New Instructors

In my class, students offer some interesting explanations of why they were surprised. For example, one student picked "historian" from the list of jobs. They said they were surprised "because historians don't use data like scientists." I thought this was an idea worth discussing and invited the class to comment. This sparked a lively conversation about data and the nature of evidence. The students had a lot of thoughtful things to say about their perception of "real" evidence. We mind-mapped their ideas about evidence on the board and tried to define "useful" data (fascinating and very discipline-specific!!).

Students realized that people often use their own experiences as data, and then generalize from those experiences. We progressed to discussing how society approaches data and the things (including data) that contribute to accepting or rejecting science.

In the end, we returned to the initial student for their opinion—they said they were still surprised that a scientist became a historian, but they had changed their mind about the nature of evidence. We rounded out the discussion by reminding ourselves to look for evidence in unexpected forms and sources while also considering that not everyone counts evidence in the same way.

13.5 Exercise 2: Reflecting to Develop an Opinion (Katherine O'Brien's Class)

13.5.1 Overview of the Teaching Activity

In this exercise, students draw on personal experiences to discover they have an opinion on a particular scientific topic (examples are provided below). The exercise incorporates written reflection and discussion. The format gives students a low-stakes opportunity to explore their ideas (in writing) before they expose their ideas to their peers (in discussion). Initially developed for a science communication course, this flexible exercise can be used in many contexts and with students at different levels of education.

The activity starts with time for students to write which allows them time to gather their thoughts and reflect (El-Helou and Kalman 2018). After this, they talk with a classmate, which gives them the opportunity to express their opinion on a topic and practice listening. The point is not to build consensus but learn to be comfortable with an opinion and use evidence from personal experience to back it up. The activity can be completed in a 1-hour class period with the potential to follow up with a longer assignment.

13.5.2 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Provide a prompt that allows students to reflect on a personal experience that relates to the course material (2.1)	Respond to the prompt either before or during class in writing	Howitt & Wilson (2015) (2.2) 15 min
Pair share (2.3)	Students share their answers to the prompt with each other	10 min
In response to thought-provoking student ideas, ask the class "What do you think? Who else was surprised by this? Why?"	Discussion can be whole-of-class or in smaller groups who then report back to the class	Discussion questions (2.4) 30 min
Wrap up. Relate conversation back to content for course.		EPA Guidelines (2.5) 5 min
Total duration in-class = 45-60 min		

Notes

(2.1) Example Prompt (A) "You will be mining your own experiences as a way to help yourself get into the mindset of the audience for informal science communication. You can view these following questions as a starting point. You don't have to answer them all. (1) What is the most memorable experience you have had at a museum; (2) Why was it memorable?; (3) Did this experience colour your expectations for subsequent museum visits?; (4) Did it change your perspective on the topic?; (5) How were people/scientists/citizens represented in the exhibition?"

Example Prompt (B) "Describe an evolutionary explanation or scenario that is particularly resonant for you. This can be an unsolved story or an evolutionary conundrum, a well-known story that you particularly like (or loathe), or an idea that was important in your intellectual development. First describe the evolutionary scenario. Then answer the following questions. (1) Where did you first encounter it? (2) What did it make you think or feel when you first encountered it? (3) Why does this scenario stick with you? (4) What principles did you learn from this scenario?"

(2.2) See References for Howitt and Wilson (2015).
(2.3) Pair-share is good for larger classrooms or if your students are shy: In pairs, students share their thoughts, then pairs share to the whole group. You can ask the students to simply share their stories. For a more structured conversation, ask students to identify a similarity in their experiences and a difference.
(2.4) Questions to promote discussion: Q1: What are some commonalities and differences you saw during your pair-share? Q2: Where do your opinions come from? Can you explain where your opinion comes from to your pair partner or to the class? Q3: What do you think about the power of emotion for forming and supporting your opinions? Q4: Do you think this emotion is isolated to your case, or do other people form opinions this way too? Q5: What does this mean for a professional situation—if you were in a meeting or a public forum? Q6: What does this mean for the public connection to science?
(2.5) The Environmental Protection Agency (EPA) document on how to resolve disagreements. It may be useful to include the principles as part of the wrap-up (U. S. Environmental Protection Agency 2020).

13.6 Top Tips for New Instructors

1. The prompts work best when they connect to course content. The first prompt given here is used in our "decolonising the museum" module; it allows students to consider the place of different groups of people in public representations of science and society. The second is very adaptable—the word "evolution/ary" can be replaced with something specific to the discipline you are teaching. In either case, students need to draw on their personal experiences with a scientific phenomenon or event when they write their reflection.
2. This exercise helps students understand why people get emotional about scientific topics. It also helps them learn to consider other people's opinions and emotions when they present or discuss a scientific topic. Students want to obtain a consensus as quickly as possible during the discussion, because it reduces the discomfort associated with emotion and personal opinions. This discussion unpacks that discomfort and helps students understand that opinions must be listened to and considered during a consensus-building exercise. The EPA document is a useful reference. It shows students how and why we should formally address and incorporate different opinions as we work to resolve problems.
3. Controversial topics can be used for this exercise but proceed with caution. You are looking for a diversity of experiences and ideas, not something where students have such strong ideas that they get stuck on articles of faith. Prompts that include reflections on evolution vs religion or mandatory vaccination are examples of difficult topics.

13.7 Exercise 3: Developing an Opinion on Published Science (Louise Kuchel's Class)

13.7.1 Overview of the Teaching Activity

This exercise can be done as an in-class discussion, written assignment, or both. Students practice offering an opinion about a scientific study. It works particularly well for studies that address an issue with multiple perspectives (e.g., conservation biology which has biological, societal, and economic perspectives). It also works well when students are learning to critique a scientific paper. The activity helps students build confidence in forming an opinion as they recognize that their scientific perspective is one of many.

Students begin by learning about a case study; I like to choose a case that is part of a larger societal issue (e.g., ocean warming; species extinction; impact of harvesting on biodiversity). Students then read a scientific paper on one or more aspects of the case study. Instructors then facilitate a discussion of four questions about the scientific paper (detailed below).

As an extension, I follow the discussion with an assignment where students are assigned a case or issue and a related scientific publication. They answer the same four questions in writing, providing justification and/or evidence to support their opinion. Marking criteria reward their work for stating an opinion, their use of logical reasoning, and consideration of multiple perspectives relevant to the issue.

As the facilitator, it is important that you identify learnings goals you would like students to achieve from the discussion and extension activity. You can alter the questions provided below to meet your specific learning goals. It is also important to emphasize from the outset that there are no right or wrong answers when offering an opinion and to establish an atmosphere where students are comfortable to offer, discuss and change their opinion.

13.7.2 Runsheet and Lesson Plan

Instructor does...	Students do...	Resources
Introduce the purpose & process for the activity (3.1)	Encounter a case study in class OR read/research case study before class	Case study resources (3.2)
Present case study using relevant resources OR summarize the case study students saw before class.		40 min

Introduce a scientific paper related to the case study.	Read the scientific paper & research its authors & their affiliations (outside class)	Scientific paper 5 min
Facilitate a discussion about each of the four questions (3.3). Wrap up (3.4)	Discussion can be whole of class or in smaller groups that report back to the whole class	Questions (3.3) 70 min
Extension Allocate a case study to each student. Students write a response to questions as a follow-up assignment (out of class) (3.5)		Task description Outside class
Total duration in-class = 110 min + out of class reading and assignment time		

Notes

(3.1) Encourage students to be open and receptive to varying opinions and emphasize that there are no right or wrong answers. The discussions prompt students to explain how they came to their opinion and invite other students to contribute different perspectives and thoughts. Recognize that there are many different stakeholders/perspectives on the issue, and each perspective is valid.

(3.2) Case study resources can include any types of information (readings, web searches, presentations, Youtube videos) related to a case that has multiple perspectives to it. For case studies with multiple perspectives ideas, the Sustainable Development Goals website provides some useful leads; click on a goal and follow links to relevant publications and webinars.

(3.3) Four questions: Q1. What do the authors state are the conservation concerns? Q2. In your opinion how well do these reflect the conservation issue? Q3. To what extent do you think the study/paper addresses the conservation issues? Q4. Are there likely to be biases in authors' views? (students should research the authors and their affiliations).

(3.4) Key points for discussion: (i) giving well-reasoned opinions is important in professional workplaces and in relation to complex societal issues. Supporting opinions with solid reasoning helps to ground conversations and lead to constructive discussion among stakeholders; (ii) it takes practice to feel comfortable giving opinions; (iii) there are always multiple perspectives and opinions on complex issues and it is OK, and often constructive, to disagree and discuss details around disagreements; (iv) conclusions in scientific studies are almost always subject to some bias.

(3.5) The marking criteria I use include: stating an opinion, how well the opinion is supported by logical reasoning; the extent to which multiple perspectives related to the issue and potential biases of the authors have been considered.

13.8 Top Tips for New Instructors

1. In some cultures, it is impolite to question conclusions and credibility of people in positions of authority (such as scientists). Students with this background may require additional encouragement and a very safe intellectual environment to participate openly in this activity.
2. Questions 3 and 4 are where students offer opinions. Questions 1 and 2 help the students ground their decision and seed their justification for questions 3 and 4. Question 3 asks students to think beyond the science to the broader context in which science is situated. Question 3 also helps students recognize the "science" perspective is one of many perspectives on an issue. For many science topics, UN's seventeen sustainable development goals (United Nations 2015) are a great way to illustrate the interconnectivity of societal issues and stimulate discussion of where and how science contributes. Question 4 aims to get students thinking beyond the science to the social context of the scientist; we are all human after all!
3. Many students are surprised by the question about author bias and struggle to think broadly about this topic or are reluctant to question it. I have found the following topics helpful in stimulating student discussion about author bias: unconscious bias, invested interests in positive outcomes, affiliations, subjectivity of interpretation, personal and cultural values, competing theories. It can also be useful for students to identify their own values/perspectives on the topic (especially in value-driven disciplines such as health and wildlife conservation). Students can ground their opinions on this topic by researching an author's website and Google for affiliations, mission/value statements, history, and other projects as well as considering the author's demographic. This discussion can bring up issues of identity, so facilitate the discussion with sensitivity.
4. The types of scientific articles that work best in this activity are studies that focus on one perspective of the issue (e.g., loss of native species), or that interpret outcomes on purely scientific values or measures. This helps to contrast that scientific perspective with the reality of multiple perspectives involved in the issue. Alternatively, issues where there are few scientific studies that overlap in what they investigate about the issue, or where the scientists have a long history in the one project (and may be invested in its positive influence) can work well.

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United Nations. (2015). *The 17 goals.* Department of Economic and Social Affairs. Online: https://sdgs.un.org/goals

Website Links

CLIPS: Communication Learning in Practice for Scientists (www.clips.edu.au) *Accessed 1 Jan 2021.*

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Katherine O'Brien is a postdoctoral fellow in the Department of Evolution, Ecology, and Organismal Biology at The Ohio State University. She is the outreach liaison for the Museum of Biological Diversity where she works on Broader Impacts, community outreach, and interdisciplinary programming. Her teaching experience includes biology courses and a service-learning course where students learn best practices in science communication.

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Understanding Your Target Audience by Profiling a Typical Member 14

Gabriel George

Engaging - Distilling - Intent

14.1 Learning Outcomes

We are so often told effective communication relies on knowing your audience. Yet identifying, understanding, and tailoring a message to your audience is still a challenge for everyone. This activity draws on an idea from radio production—the audience of one. It presents students with a very simple exercise to connect with their audience by creating a profile for a typical audience member. The profile allows students to generate targeted strategies to enhance their communication with that typical audience member. By the end of the exercise, students will be able to use a profiling tool that helps them know their audience and feel more comfortable communicating with them.

14.2 Teaching Context

This tool is designed to help students tailor their communication to their audience or audiences. It is particularly useful when students are tasked with communicating to an audience they will not directly interact with, such as members of the public through a podcast, or politicians through a policy briefing. I have seen it used to guide the preparation of science radio segments, scientific seminars, communication strategies for conservation projects, and TikTok videos.

This activity can be implemented as a short introductory exercise at the beginning of a project to get students from any level and discipline thinking about their audiences early in the planning process. It is easily adaptable to in-person or online

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contexts for traditional or creative assessment pieces. It can take between 10–30 min depending on how audience-oriented students need to be when communicating.

14.3 Overview of the Teaching Activity

The exercise begins with a brief description of the audience of one and shows students an example profile of a typical audience member. Students are left to identify how many distinct audiences they intend to communicate with. They then create a profile for a fictitious person who represents a typical member of each audience (Fig. 14.1). Profiles include general demographic information, scientific interests, media consumption, and level of understanding of relevant topics. Students pick out which features from the profile will be important to consider when tailoring their communication. They subsequently use those features to generate strategies to effectively communicate with their intended audience(s). Students share their strategies in small groups to exchange ideas. These profiles and communication strategies are used by the students throughout the remainder of their project, be it a traditional scientific report or creative audio-visual content.

14.4 Runsheet and Lesson Plan

This lesson plan is created for an undergraduate or postgraduate level class and can be used as a standalone assessment or as part of a larger assessment. The length of the exercise can be altered as needed by removing or increasing the details included in each audience profile.

HENRY 27[1]
BRISBANE, AUSTRALIA

BIOGRAPHY

Henry was brought up in the inner suburbs of Brisbane[2]. He went to the same school his whole childhood before heading to university to study social work. He hasn't had any formal training in natural sciences since high school[3]. His mother worked as a sustainability officer for the local council and his father is a keen surfer. Sometimes his dad would take the family along to the beach[4] and they would always pick up fish and chips on the way home[5]. Henry moved to Melbourne after graduating[2] where he got a job working in a small restaurant in Melbourne for a while after graduating. While there, he got into the habit of catching small snippets of news over the radio while working in the kitchen. Usually, though, he just wished the radio announcer would stop talking and play more music[6]. Henry now works in the field he studied in back in Brisbane but still flicks on the radio or a podcast most days when cooking dinner[6]. He still grabs cheap fish & chips when he can't be bothered cooking[5]. Henry picked up being eco-conscious from his parents and carries his own straw with him to his favourite cafe near work[4].

COMMUNICATION STRATEGIES

1. Keep language, style, and format engaging for a younger audience.
2. Keep the subject matter relevant to Brisbane and Melbourne.
3. Language should be understandable to anyone with an environmental interest but no formal science education since high school.
4. Utilise eco-conscious mindset by clearly communicating how the subject matter relates to well-known environmental issues.
5. One goal of the communication should be changing this behaviour.
6. Communication needs to be delivered in a short, easily digestible format like a news clip over the radio or podcasts without scientific language.

Fig. 14.1 An example profile for a typical audience member. In this case, the student is tasked with communicating the impacts of flake consumption on shark populations to environmentally conscious members of the general public. The audience is not well versed on the impacts of their actions but is likely to be interested if those impacts can be well communicated. This example is only intended as a guide, not a strict template. Numbers and associated colours illustrate how biographical information can be targeted to produce specific communication strategies

Instructor does…	Students do…	Resources
Inform students of your goal(s) for the audience profiles (1).		 2 min
Introduce the importance of knowing your audience and invite student comment why this is important. Provide an example audience profile (2, 3).	Contribute ideas around why knowing an audience is important, and how communication could be tailored to them. Read example audience profiles.	Example profiles. 5-10 min
Answer questions and troubleshoot with students where necessary as they write their profiles.	Identify each unique audience the student intends to communicate with. Create a profile of a typical member from each audience (3 - 6). Identify targetable features of each typical audience member and use those features to plan communication strategies (7).	Digital or physical tool for students to write on. 10 min
Split students into groups and facilitate discussion about profiles.	Workshop audience profiles in groups and refine strategies for communicating to those profiles (8).	 5 min
Invite groups to report on a profile and their communication strategy.	Share ideas with the class.	3 min per speaker
Total duration in-class = *25 - 50* min, depending on level of discussion and student numbers.		

Notes

(1) The goal(s) will depend on the task at hand. For instance, if students are tasked with developing a full communication strategy, their goals will be: (a) identify their audience; (b) understand how to effectively communicate with their audience; and (c) improve their communication by becoming more comfortable with their audience. If students are working on a specific assessment task, the audience may be pre-defined. If so, their goals will just be parts (b) and (c).

Students may also have goals of changing certain beliefs or behaviours in their audience.

(2) Prepare by reading some online resources about the audience of one, often referred to in radio production contexts.

(3) Emphasise the purpose of these profiles is to make an audience more concrete and humanised, *not* to overlook diversity within the audience. When students later use the profiles to target their audience, ensure they avoid communication strategies that might exclude other audience members.

(4) It is important to create one audience profile for each independent audience the students intend to reach; this helps students understand the difference between audiences. For instance, if an assessment requires students to write a scientific report for policymakers and an accompanying press release for the general public, different profiles are needed for the two audiences. Conversely, two scientific reports on different subjects but for the same audience would likely only require one profile. If you are seeking to expand your audience, the profile should represent a typical member of the new audience rather than your existing audience.

(5) The profile does not need to follow a stock outline. It is up to students to paint the picture of a typical audience member. Good places to start include: general demographic and geographic information, scientific interests, level of understanding of relevant topics, media consumption habits, professional background, and lifestyle.

Crucially, the profile should be specific. A profile of a typical audience member should not just say "young male in full-time work who likes music and the environment". It should instead say "Henry is a 27 year old social worker who brings his own straw to the local cafe and wishes the people on the radio stopped talking and played more music". Make this person real. Write about them as if you were writing about a friend. It is much easier to target your communication when you know specifically who the target is. Adapt the level of detail students should include based on the time you wish to dedicate to the exercise. Some students may not feel comfortable with the more creative side of writing a profile, but make sure everyone at least writes some dot-points addressing basic biographic information and media consumption habits for their typical audience member.

(6) Leave students to have fun and independence when they create their audience profiles. Even if only part of the profile is directly used to tailor their communication, the rest of the profile helps to humanise the audience. The profiles can include deep backstories that recount major life events, visual sketches, quick demographic notes, or lists of favourite media (e.g., books, podcasts, and news sources). Whatever the students produce in their profiles, make sure they tie some features of their typical audience member back to communication strategies. If your typical audience member only consumes news media when it comes over the radio in the kitchen they work in, you will need strategies that make your communication quickly digestible and easy to follow when the audience is distracted with other tasks.

(7) Communication strategies should always include stylistic decisions on tone, formality, and language. Feel free to incorporate other theories and exercises from this textbook into creating communication strategies for a profiled target audience. You may also like to have students use a language level estimator tool on written content so they can get quick feedback on where their communication can be enhanced to better match their audience. See the Relevant Chapters and Further Reading/Exercises for suggestions and tools.

(8) Students share their audience profiles within small groups, where they can help each other refine their communication strategies. I find it is useful here to also discuss how the message can best be tailored to the audience member's environment (e.g., Are they working in a noisy environment where they will likely only hear snippets of information?; Do they have a good data service where they can view video on their phone?; Are they working in an office where people will share in policy and philosophical discussion?). These factors can affect both the communication medium and the depth of information and audience can access.

14.5 Top Tips for New Instructors

1. Introducing this exercise as a technique from radio helps engagement. Students love getting a little peek into the world of radio production rather than just being asked to complete another peer-reviewed science communication exercise.
2. There are up to three key outcomes from this activity depending on the context it is used in. Unless an audience is pre-defined, the primary purpose of the exercise is for students to identify who their audience really is—taking the abstract idea of a faceless crowd and turning that into a real person to talk to or write for. Secondarily, having this concrete idea of a typical audience member allows the student to come up with communication strategies to target their message. Finally, identifying and understanding your audience by thinking of a single person in that audience makes communication a far less daunting endeavour. In short, communicating to the audience of one helps us identify, understand, and feel comfortable with our audience.
3. Through my own experience, I have found a welcome side-effect of communicating to an audience of one is you tend to improve the overall quality of your communication. The most effective communicators do not engage their audience by making every individual in it feel like part of a crowd; instead, they make each individual in the crowd feel that they are being directly spoken to.

Website Link

BBC Academy for more communication tips from radio. (https://www.bbc.co.uk/academy/en/). *Accessed 30 Jan 2021.*

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Using Active Learning Techniques to Engage Audiences in Oral Presentations

15

Sara Mazrouei and Michelle Schwartz

Engaging - Speaking - Intent

15.1 Learning Outcomes

Active learning activities are designed to help participants interact and engage with others, as well as with the content being presented. Active learning has been shown to improve content retention while also increasing critical thinking (Anderson et al., 2006). Active learning activities can also be used in different settings and contexts to assess knowledge at different stages of a learning experience.

After completing this workshop, the participants will be able to apply the principles underlying audience engagement and active learning to design and deliver effective, engaging, participatory, and learner-centered presentations.

15.2 Teaching Context

In the workshop, participants learn about active learning techniques and how to use the BOPPPS (Bridge, Objective, Pre-assessment, Participatory learning, Post-assessment, Summary) model (Pattison & Day, 2006) to structure their presentations and engage their audience. Participants develop a short presentation on a topic of interest. They complete an outline of their presentation using a BOPPPS template. Later, they deliver the presentation to their fellow participants and receive feedback from their peers on whether the presentation was comprehensive, actively engaging, and inclusive of all participants.

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Ideally, this workshop would be run in a course where participants are expected to deliver an oral presentation and where one or more of the learning outcomes are tied to communication or audience engagement.

This workshop can be used for science students who are presenting in groups or individually. It can also be modified to reflect a relevant disciplinary format, such as a capstone project presentation, a public engagement event, or a professional conference.

15.3 Overview of the Teaching Activity

During this workshop participants are introduced to different methods of engagement for active learning, learn to recognize appropriate contexts and settings for each activity, learn to value the active involvement of participants in their own learning experiences, and begin the process of designing a thoughtful presentation using the BOPPPS model rather than simply putting slides together.

This entire learning experience is itself structured using the BOPPPS method as a way of demonstrating how to use the BOPPPS model and to showcase its effectiveness at engaging participants. The six elements of BOPPPS are:

1. *Bridge in*: Get the audiences' attention and motivate them to see why they should care about the topic of the presentation.
2. *Objective(s)*: Make the goal and objectives of the presentation clear to the audience.
3. *Pre-assessment*: Assess what the audience already knows about the topic.
4. *Participatory learning*: Get the participants actively involved in the learning process.
5. *Post-assessment*: Determine whether participants have achieved the objectives of the presentation.
6. *Summary*: Provide a takeaway message, and review the content provided in the presentation.

After the workshop, participants design a short presentation enhanced with discipline-specific active learning activities that will engage and motivate their audience. Later, they deliver their presentation with the new activities in place and solidify their learning by engaging in peer feedback.

15.4 Runsheet and Lesson Plan

The BOPPPS method for creating a presentation outline is a core component of the Instructional Skills Workshop (ISW), an internationally recognized teaching development program that is structured around participants delivering short presentations and receiving feedback from their fellow participants. We use the BOPPPS method as a simple way to design and deliver effective presentations while also encouraging the thoughtful application of active learning principles.

BOPPPS is a method of drawing participants into a presentation. It provides clear learning goals and engages participants with content leading to deep or long-lasting learning. The BOPPPS model also helps presenters become more confident and reflective in their teaching and presenting.

This workshop can be as short or long as you would like—it depends on the length of the activities you choose, how deeply you want to explore the pedagogical theory of active learning, and how much time you would like to allow for presentations and peer assessment.

The examples provided below are what we have used. We use "Presenter" and "Audience" as well as "Instructor" and "Student" titles. This is because, when an Instructor teaches their students to use this method, they are modelling "Presenter" practice. As participants, the students are modelling "Audience" practice. We also provide a "Workshop Instructor Example" (for how the teacher can present this in class) and "Science Presenter Example" (which may help students consider how to adapt BOPPPS to their presentation work).

<table>
<tr><th>Presenter (Instructor) does…</th><th>Audience (Students) do…</th><th>Resources</th></tr>
<tr><td rowspan="2">B - Bridge In

This can be an icebreaker activity, a question, or an interesting fact or story related to the presentation's content that stimulates discussion.

Workshop Instructor Example:
What are some characteristics of engaging presentations?

Science Presenter Example:
What is the most recent news around COVID-19 vaccines?</td><td rowspan="2">Complete Bridge In

Discuss the starting question using method of choice (e.g., group brainstorm with answers written on a board, virtually over Google Docs, or in small groups as a think/pair, share activity) (1).</td><td>Icebreaker, question, story, or fact to stimulate discussion.</td></tr>
<tr><td>10 min</td></tr>
<tr><td colspan="2" rowspan="2">O – Objective(s)

Explain the workshop's objectives (note this is not a participatory activity, so student interaction is not included here). In this example, students are preparing for an upcoming talk in which they will use active learning (note Resources for this section).

Workshop Instructor Example:
By the end of this workshop, participants should be able to:
1. Recognize the importance of having a clear presentation structure with a plan for active engagement (e.g.,BOPPS).
2. Explain different parts of the BOPPPS presentation delivery model and associate proper active-learning strategies
3. Demonstrate their understanding of active-learning techniques by creating their own examples (2).

Science Presenter Example:
1. Recognize the importance of clinical information related to COVID-19 disease and immunization.</td><td>Assessment rubric and task description for their upcoming talks.</td></tr>
<tr><td>10 min</td></tr>
</table>

P – Pre-Assessment Before going too deeply into content, it's important to determine what your audience already knows about the specific topic you will be covering (in this case, active learning techniques). *Workshop Instructor Example:* Gallery walk – "List some ways in which you've engaged in active learning". (You could also use other active-learning activities to determine students' existing knowledge, such as a poll, a one-minute paper, or a give-one-get-one). *Science Presenter Example:* Poll (yes/no) question – "I know the difference between mRNA and viral vector vaccines".	*Complete Pre-Assessment Gallery Walk* In groups of about four, participants go to different areas of the room to discuss how they've engaged in active learning in their own studies. They record their ideas on paper or a whiteboard. Participants then move around the room listening to each group take turns presenting on what they've written. In the end, the instructor collects the suggestions and provides the full list of active learning methods to the group for use in their presentation planning.	Paper or whiteboard Marker pens 20 min
P – Participatory Learning Activity Every workshop needs at least one main activity where the participants directly engage with the topic (e.g., a case study, a discussion, a debate). *Workshop Instructor Example:* Presentation planning worksheet *Science Presenter Example:* Divide audience into four groups. Ask each to create a pro/cons list on one of the following vaccines: Pfizer, Moderna, Johnson and Johnson, and AstraZeneca.	*Complete Participatory Learning* Students are divided into their presentation groups and given a paper copy or Google Doc version of a presentation planning template with sections for each component of BOPPPS to structure their presentation. They plan their presentation together.	BOPPPS presenter's planning template 35 min

P – Post-Assessment Before ending the session, it's important to gauge the audience's understanding of the presented content. This could be a quick verbal check-in or a more formal exit activity. *Workshop Instructor Example:* Debrief conversation and worksheets *Science Presenter Example:* Ticket out the door (3) with two questions: What is one thing that you learned from my presentation? What is one thing that you are still unclear about?	*Complete Post-Assessment* Students complete review of the work they've done on the presentation planning templates. Each group shares a brief description of how they have structured their presentation while also putting this on a worksheet for submission. Fellow students provide feedback or suggestions – these are also recorded on the worksheet.	Debrief activity Worksheets to collect responses. 10 min
S – Summary Recap the main points and refer back to the session learning objectives (4). *Workshop Instructor Example:* Review the expectations for the upcoming presentations, including the rubric you will use to facilitate peer assessment. *Science Presenter Example:* Takeaway Slide with one Tweet summarizing the presentation.	*Complete Summary* Students comment on their understanding of the learning objectives and make concrete plans for their presentations. Students prepare (out of class) for their presentation in a later session (5).	Assessment rubric and task description for upcoming student talks (6) 5 min
Total duration in-class = 90 min + post-class group work on the presentations		

Notes

(1) In a think-pair-share (Kagan, 1994), the instructor/presenter poses a question or a statement and asks participants to think and reflect individually. Then they ask participants to pair up and share their ideas. Lastly, each pair is asked to share back with the larger group

(2) You can use Bloom's Taxonomy to select action verbs that align with your desired level of learning for the audience

(3) A ticket out the door activity (Fisher & Frey, 2004) asks participants to answer a specific question before leaving the presentation

(4) This is a good opportunity to review how the workshop itself was structured with BOPPPS
(5) When the participants reconvene to deliver their presentations, enabling effective peer feedback by providing participants with a peer feedback form. Depending on the time that participants have to complete the feedback form, you can include quantitative or qualitative questions using scales, rankings, or open-ended responses
Share the feedback form for student presentations before their presentations. Here are sample questions you can use:
   (a) The presentation followed a clear structure, such as the BOPPPS model
   (b) I was able to participate in this presentation
   (c) Rate the level of learner engagement in this presentation (1 through 7)
   (d) What is one thing you found particularly effective in this presentation?
   (e) What is one suggestion you could make to improve this presentation?

After each presentation leave time for participants to complete the forms
At the end of the presentations, help the groups get together and give them the written peer feedback to discuss. This immediate feedback lets groups reflect while they are still together. You, as the instructor, can also provide your own feedback and help them reflect on their peers' responses
(6) The assessment rubric and peer feedback form for the student presentations can use similar metrics

15.5 Top Tips for New Instructors

1. Groups larger than five can become unwieldy and prevent an even distribution of presentation tasks.
2. Peer evaluation becomes draining if participants are required to actively engage with too many presentations. In a large class, divide the presentations over several sessions.
3. If students are unfamiliar with a peer feedback model, allot time to review models for constructive criticism, or have participants develop a class contract together. This is a good opportunity to review the role of peer review in science.

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Further Reading/Exercises

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Yang, Y., You, J., Wu, J., Hu, C., & Shao, L. (2019). The effect of microteaching combined with the BOPPPS model on dental materials education for predoctoral dental students. *Journal of Dental Education, 83*(5), 567–574. https://doi.org/10.21815/JDE.019.068

Website Links

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Graduate Teaching Development Program, Ryerson University. (https://www.ryerson.ca/learning-teaching/ta-ga/professional-development-program/). Accessed 25 Jan 2021.

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Part III

Practice Writing

Tackling Problem Writing Using Online Analysis Tools

16

Susan Rowland

Writing - Distilling - Intent

16.1 Learning Outcomes

When students write scientific material, they often get bogged down using long, complex sentences. They also frequently use nominalisations and passive voice because it makes their writing sound more "formal". Unfortunately, however, this "formal" writing can become confusing and hard to read and is increasingly discouraged by scientific journals (Hillier et al., 2016; Plavén-Sigray et al., 2017).

After completing this exercise, students will be able to simplify their writing so that it is clearer, simpler and more readable. They will also learn that a long sentence is not always a good one. The exercise uses two online text analysis tools—The Writer's Diet and Hemingway Editor. These tools both identify elements that contribute to poor writing. The tools will not rewrite the students' work for them, but they will highlight elements of the writing that can be changed.

16.2 Teaching Context

This exercise is useful in any class where you want to help students improve their writing. It is particularly useful when you want students to write less formally or make their formal writing less turgid. The students and the instructor don't need a sophisticated working knowledge of English grammar to complete this exercise.

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The activity can be done in 1 h or in a longer 2–3 h workshop. The session length depends on the amount of time you want students to spend improving their writing. The tools are free to use, so students can return to them at any time after the class.

The tools help students recognise long complex sentences, excess prepositions and other superfluous words and grammatical constructions in writing. In particular, the exercise can be used to raise students' awareness of nominalisations. Helen Sword describes nominalisations as "zombie nouns", because they "cannibalize active verbs, suck the lifeblood from adjectives and substitute abstract entities for human beings" (Sword, 2012).

Nominalisations are nouns that are made from verbs or adjectives by adding a suffix (-tion, -ness, -ment, -ship, -age, -al, -ance, -ing, -ery, -th, -ism, -ise or -ity). So, for example, explain can become nominalised to explanation, explainism (a new life philosophy in which everything is explained) or explainisation (a new name I just made up for the act of explaining). Some of these options are sillier than others, but they all sound quite formal!

Although Helen Sword hates nominalisations, there is nothing wrong with them per se. The issues begin when the nominalisations get in the way of making sense (or hinder your explainisation!)

The runsheet gives some helpful websites and resources.

16.3 Overview of the Teaching Activity

The first part of this exercise introduces some key elements of English that can engender bad writing practice. The two tools *The Writer's Diet* and *Hemingway Editor* are introduced, and students are shown how to access them.

The instructor can ask students to test their own writing in the tools, or the instructor can provide a writing sample. In either case, students work to improve a piece of text by putting it into the tool and then making modifications. They test for improvement by running the amended text through the tool again.

It is important to note that overzealous simplification of text can destroy all the beauty and character of the writing. Thus, the simplification exercise can form the basis of a class discussion in which students consider how to best modify a piece of writing (rather than how to just get the best scores on the tools).

16.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Explain the purpose and wider application of the exercise (to improve the quality and clarity of our writing). Describe and formally name some problem areas that writers stray into when writing formally (1).	Work with the instructor and relevant websites (2) to find definitions and examples of troublesome practice. Watch the Zombie Noun video.	Zombie Noun video (3) and other sites if needed. 10 min
Introduce *The Writers Diet* and *Hemingway Editor* websites (4).	Access the sites and explore the apps and support notes.	Web apps 3 min
Introduce the piece/s of writing (5). Ask students to examine the writing and discuss what they like and what they don't like about the piece.	Discuss the writing and give ideas on what is good and not so good about it.	Writing samples (5) 5 min
Give students freedom to improve the piece/s by using the tools and iterating on the writing (6,7). Ask them to push the piece of writing to the point where it has the best possible score on the tools. Ask students to keep a copies of the text at various points.	Put the piece/s of writing into the tools. Work to change the scores for the pieces of writing by modifying the text. Keep copies of text as follows: (i) the original text; (ii) the text where it reads the best; and (iii) the text with the lowest score.	Computer and internet access. 20 – 120 min
Invite students to compare their saved texts and discuss what they learned and how they will use these tools in the future.	Contribute ideas. Compare texts.	15 min
Total duration in-class = Minimum 60 min but can be up to 2 or 3 hours.		

Notes

(1) These errors include (a) nominalisations, (b) long sentences, (c) passive voice and (d) excess adjectives

(2) Your students may need other support websites to help them with their writing and understanding of particular terms (e.g. nominalisation, passive voice, adjective). It can be useful to give them the opportunity to find online definitions and examples of practice. You can suggest websites or encourage them to find their own sources. Example site: Gillett, A (2021) Grammar in English for Academic Purposes: Nominalisation
(3) Sword, H (2012) Beware of nominalisations (AKA Zombie Nouns). Youtube: https://www.youtube.com/watch/dNlkHtMgcPQ
(4) The Writer's Diet and Hemingway Editor sites both have useful commentaries. The Writer's Diet is particularly rich; it also has a plug in app for Word. This is really valuable for students
(5) There are several ways you can introduce text. You can supply a "bad" piece of writing and ask students to improve it. You could ask students to bring a piece of their own writing. You could also ask students to bring two pieces of writing—one they find easy to read and another one they think is hard to read
(6) Students can work alone or in pairs. It is important to encourage conversation and working "out loud", so give students time and opportunity to discuss their ideas with each other as they use the tools
(7) An extremely "good" score on the tools does not always equate with elegant writing. Invite students to discuss the point at which the writing still had personality and beauty and then the text that had the best score. Ask the students to make a value judgement about where the "best" writing appeared in their sequence of refinement

16.5 Top Tips for New Instructors

1. Don't labour the pre-discussion (before students put the writing into the tools). Students are (a) not very tolerant of long grammatical explanations and (b) usually are not good at describing the technical aspects of why writing does or doesn't work. They will find the work easier if you get them to talk about what they are changing as they improve their writing scores in the tools.
2. This exercise works better if students are given plenty of time to test the writing sample and improve it using the tools. Let them organically tinker with their writing so they improve their scores. The Writer's Diet is particularly good at highlighting specific elements of the writing that are undesirable.
3. It is productive to get students to work on improving a piece of writing as a pair—this way they can talk, draft, test, fail and succeed together. The conversation is important for their learning, and it's more fun and productive to do this work with a partner.

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Plavén-Sigray, P., Matheson, G. J., Schiffler, B. J., & Hedley, W. (2017). The readability of scientific papers is declining over time. *eLife, 6*, e27725. https://doi.org/10.7554/eLife.27725

Further Reading/Exercises

To give students more support in improving their writing, use www.clips.edu.au.

Website Links

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17 Learning to Write from the Way You Read

Louise Kuchel

Writing - Organising - Investigating

17.1 Learning Outcomes

Graduates entering the workplace will encounter many new contexts for writing. This activity equips students with an approach they can use to begin any unfamiliar writing task. Students learn to recognise and unpack the structure and content of a large written piece from the way they read it. After completing this activity, students will understand the key functional parts of a piece of writing, including (1) the locations of messages and explanations; (2) the importance and function of images, figures and signposts; and (3) the types of information included in different sections. Students create a dot-point summary of what they read. They annotate their summary to create an organisational structure/template for their own writing.

17.2 Teaching Context

This activity is useful for students to complete before they embark on a large written assignment. It introduces students to how and why larger written pieces are structured in specific ways and to techniques they can use to plan their own writing.

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I typically base this activity on reading and writing scientific research papers, but I have also used other forms of science writing as the stimulus (e.g. reports for business audiences and email messages to colleagues).

This activity is suitable for middle undergraduate through to graduate level classes, for all science disciplines, and is a generic approach that can be applied to the many forms of writing that science graduates may encounter in the workplace.

17.3 Overview of the Teaching Activity

The activity begins by asking students to skim-read a scientific paper (or other stimulus) and then reflect individually on which parts they read first, second, third etc. The whole class then shares their reflections in a group discussion where universal similarities are noted on a whiteboard. This leads to discussion about why students read it this way. I find students always note that both readers and writers have a purpose for their communication and that readers have expectations about where to find certain types of information. We discuss the structure of the whole article and individual paragraphs, noting features like the location of key messages and explanations, signposts to the reader, the purpose of figures/images and the location of explanations. Students then create a dot-point summary of the article they read, which serves as a template for their own writing. I explicitly highlight to students that, when they encounter a new writing task in the workplace, they can request an exemplar and use this approach as a starting point to their writing.

17.4 Runsheet and Lesson Plan

Instructor does...	Students do...	Resources
Provide exemplar article	Read article (1)	Article (2) 10 min
Ask students to list the order they read the article (3).	Reflect individually or in pairs and make list	 5 min
Facilitate discussion (4). Record order on white board (5). Record reasons on whiteboard (6).	Share/discuss with peers the order and why they read in that order	Whiteboard 25 min

Instructor does…	Students do…	Resources
Explain how a dot-point summary is useful to distil messages from reading and as a template for structuring unfamiliar writing tasks (7). Give how-to instructions (8).	Work in pairs to create a dot point outline of the article and annotate with descriptions of the type and/style of information in each section (9).	Student access to exemplar article 30 min
Extension The instructor describes steps in the writing process using an image (10); students annotate the image (11).		Image of the writing process (10) 20 min
Extension Instructor introduces students to the 'Writing' section of the *CLiPS at University* website (12); students explore the website.		Internet access 10 min
Total duration in-class = 70 min + 20 min in-class extension		

Notes

(1) Can be done before or during class
(2) The article can be any genre of writing about science, short or long
(3) Encourage students to be honest about how they read, and not write down how they *think* they are supposed to read
(4) Prompt questions include: In what order do you read scientific papers? Hence, what do you think are the most important parts of a scientific paper for a reader? Why did you read that section first/next/last?
(5) The aim here is to have students identify title, abstract, first paragraphs, first sentences in paragraphs, visuals, headings and conclusions. These are what a reader uses to decide whether to read more of the article
(6) Some important features to highlight in this discussion include: Readers expect to find specific types of information in specific sections; the purpose of the communication is important from a reader's and writer's perspective; signposts like headings help guide the reader; key messages are in prominent and predictable locations; most people look at figures/visuals before reading text; supporting arguments and explanations are typically found in the middle or end of documents
(7) Here I reiterate that employers usually don't provide detailed instructions for writing tasks, but graduates can request a good example and use this approach to begin their own instructions
(8) Dot-point summary instructions: write one dot point per paragraph that summarises the key message from that paragraph (a well-written piece contains one main idea per paragraph). Include headings and sub-headings

(9) Annotations can include anything the student finds useful. It is useful for instructors to prompt students and help them recognise different conventions used in organising the information, structuring the paragraphs and in the style and language used. Instructors new to this idea may find the list of core skills in Mercer Mapstone and Kuchel (2015) a useful starting point, along with theory chapters listed below
(10) There are many suitable images of the writing process available on the internet. In my opinion the most useful for students include the following steps and cycles: brainstorming, research, ordering/organising, drafting, wordsmithing, editing and proofreading. I like the image available at the website shown in the Resources
(11) Examples of what you could ask students to annotate on the image include: (a) Indicate a point in the writing process that you could deconstruct an exemplar or create a dot-point outline from an exemplar; (b) add your personal timeline for writing the assignment
(12) The CLiPS website is designed as a resource for university science students. The 'writing' section contains practical information and examples how to organise and structure scientific articles, paragraphs and sentences (Rowland et al. 2018)

17.5 Top Tips for New Instructors

1. This activity works best when students deconstruct a genre they are familiar reading, such as a scientific paper.
2. Students love it when instructors admit to not reading entire articles; it helps loosen them up to share how they really read.
3. It can be hard to find an exemplar that is well written throughout, especially at the scale of paragraphs and sentences. As such, this activity works best for bigger picture discussions about structure, language, use of images and so forth, unless you can source a very well-written article in the genre you want. I strongly recommend asking colleagues or your university's writing centre for good examples.

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Further Reading/Exercises

Students' writing process can be supported through CLiPS (Communication Learning in Practice for Scientists) www.CLiPS.edu.au/university (Rowland et al., 2018). This site has been designed to leverage students' interest in assessment success, and thus the content is focused on helping students improve their university-level assignments.

Website Links

Berkeley Writing Course. (https://auth.berkeley.edu/cas/login?service=https%3A%2F%2Fbcourses.berkeley.edu%2Flogin%2Fcas). *Accessed 1 Jan 2021*.

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Abstracts as Puzzles: A Teaching Tool for Research Summarization

18

Stephanie N. Lewis and Anne M. Brown

Writing - Genre - Organising

18.1 Learning Outcomes

Professional scientists are asked to convey the significance of their work to others through a variety of mediums and to broad audiences. Abstracts, defined as short (~150–300 words) summaries of a complete work, are often difficult to conceptualize and write for both specific and lay audiences.

After completing this exercise, the learner will be able to deconstruct an abstract while reading, construct an abstract for their own written works, and be a critical reviewer and consumer of information written in abstract form. This exercise involves learners envisioning an abstract like a puzzle with an associated active-learning activity that includes reviewing good and bad abstracts, writing their own abstracts, and critiquing peers.

18.2 Teaching Context

Brief summations of a research study can be challenging to compose when the details of the study make conveying the ideas easier (Schimel, 2012). As a vehicle of communication, the abstract allows students to engage in professional research spaces like conferences, symposia, and meetings from a variety of disciplines and fields. Undergraduates and graduate students need interactive, scaffolded approaches when learning how to write, read, and critique effective abstracts (Christian & Kearns, 2018). This repeatable abstract activity can and has been performed in

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research lab meetings, introductory research practice courses, and training workshops for instructors.

This activity can apply in spaces where undergraduates and graduates are engaging in the research process, either as new or practiced researchers. We have implemented this activity in Summer internships, course-based undergraduate research experiences, undergraduate research for course credit, first-year disciplinary courses, and graduate orientation workshops.

18.3 Overview of the Teaching Activity

In this activity, learners conceptualize and reconstruct an abstract like a puzzle as they review effective and ineffective abstracts. The practice aids their abstract writing process and critiquing of peers. The instructor selects a variety of abstracts from different scholarly journals. These abstracts possess both good and bad aspects of summarizing a research study.

After a short lecture on the general format and the content that should be included in an abstract, groups of students are challenged to reconstruct abstracts that have been cut into single sentences (provided in random order). Each student group reconstructs both a “good” and a “bad” abstract and their experiences are compared. Students are led through a reflective conversation, helping them understand any errors in the reconstruction. Students discuss the composition and meaning of the sentences as part of their critique. Language clues become a popular conversation topic for strategizing what does and does not work when writing an abstract and conveying the importance and scope of their work accurately.

This learning activity begins to fill the knowledge gap around how to clearly and concisely convey a research study. Students report that they find the activity fun and they appreciate the opportunity to explore building an abstract in the context of assembling a puzzle. The exercise breaks down the process of writing an abstract “sentence by sentence.”

18.4 Runsheet and Lesson Plan

Before the in-person activity, the instructor identifies several abstracts that they deem effective or ineffective at communicating a study. To prepare the activity, copy the abstract into a document editing program and add blank spaces (line carriages or returns) between sentences. Rearrange the order of the sentences. We use two options for providing the jumbled abstracts to students:

1. Print the scrambled list of sentences and cut each into a slip of paper. The stack of paper slips is presented to the students.
2. List the sentences with proceeding blanks onto which students can write a number corresponding to the order. The abstract is presented as a completion worksheet.

Keep a copy of the original abstract for the students to review after their attempt at rearranging the sentences or have a citation available so students can search online and confirm order accuracy.

The preparation time varies depending on the number of abstracts needed. Approximately 60 min is required to identify and prepare six abstracts.

Instructor does…	**Students do…**	**Resources**
Introduction to abstracts: What are they? Why and where are they used? What is the general structure? What journal-specific formats are used?	Observe, take notes, contribute ideas	 10 min
Separate students into groups of 2-3. Provide each group with a deconstructed abstract (1).	Work as a group to evaluate sentences and discuss order. Arrange or label sentences accordingly.	Deconstructed abstract (1) 10 min
Provide copy of original abstract or ask students to find article using citation information provided by instructor. Poll group to get sense of accuracy.	Compare group's order to original abstract. Discuss why they arranged the sentences the way they did.	Original abstract 5 min
Make sure that students understand the foundational structure of abstracts (2).	Link the way they arranged the sentences to their understanding of the structure of abstracts.	 5 min

Instructor does…	Students do…	Resources
Provide each group with a second scrambled abstract to reassemble and critique. Have them check against the original. Consider how the structure fits with the standard abstract structure.	Work as a group to evaluate the sentence order and arrange the sentences in what they believe to be the logical order. Compare the group's guess on order to the original.	Second scrambled abstract 15 min
Facilitate discussion around the words and phrases that influenced students' decisions on sentence order. Pose questions: Which aspects of the abstract helped/hindered your process? How do the writing choices impact reader comprehension? What best practices can we set as a group to mirror the successful parts, and avoid the ineffective elements?	Engage in discussion with instructor and peers about the effectiveness or issues with the composition of the abstracts (3). Discuss aspects of the writing that helped with ordering or were confusing.	15 min
Total duration in-class = 60 min		

Notes

(1) Pull abstracts from disciplinary and field-specific journals for examples closest to what students would write. You can rearrange the sentences manually, or you can assign numbers to each sentence and use an order randomization tool (e.g., https://www.random.org/lists/) to guide your work.

(2) For this activity, abstracts are taught as consisting of background information, approach, summary results, major conclusions, and broad implications. We

break down how many sentences are recommended for each section of the abstract (background, methods, etc.) as to ensure all information is included. This breakdown of sentences helps students "check off" the information provided and have more complete abstracts.

(3) For research mentoring, encourage senior-level students to share conference/symposium experiences and conversations precipitated by their abstracts.

18.5 Top Tips For new Instructors

1. Summarization is a skill that can be applied in many contexts and learning environments (Brownell et al., 2013). For instance, summarization by clinicians of patient information can translate to successful health management outcomes for patients (Feblowitz et al., 2011). The activity in this chapter focuses on research abstracts as the vehicle for learning summarization, but any type of summary with a relatively standard structure could be used.
2. This activity could be adapted for explaining writing items like annotated bibliographies, executive summaries, and literary synopses. Establishing the required framework upfront is key to helping students understand why the parts are required, why the order of those parts is important for readability, how word choice impacts comprehension, and how to compose their own paragraphs. We use published abstracts to highlight the amount of content for each section of the abstract. Using "good" and "bad" abstracts helps students understand how communication practice affects audience experience.
3. Critique of scholarly works is a valuable research skill across all disciplines. Our experiences suggest students enjoy critiquing published research articles, which is a necessary skill set for science professionals participating in peer review. Anecdotally, students who complete this activity show an improved ability to summarize their work (we can make this statement from a comparison of their pre- and post-activity compositions).
4. You can expand on the learning opportunities associated with this practice by enlisting senior-level students and graduate students to identify relevant abstracts. The students can test their ability to critique work and you can evaluate their critiquing abilities. The added benefit to the instructor is a reduction in the preparation time.
5. You do not have to select a consistent set of abstracts for this activity. Variation in formatting, style, organization, and word choice improves the quality of the discussions! Be careful to align the best practices discussed with the students' assessment rubrics. You may need to edit and redirect during the group discussion to ensure this alignment happens.
6. If you chose to cut and provide slips of paper, be mindful of cut edges. Students may opt to assemble slips based on the cut edge shapes (rather than the content of the sentence). To ensure the cut edges do not inadvertently reveal the correct order, mix up the sentences before cutting them down into slips.

7. Group size can impact learning. Smaller groups (2–3 students) work better. In larger groups the students cannot all touch and see the paper slips during rearrangement; this leads to group-member exclusion.

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19 Jargon and Audience Awareness: Improving Science Writing Using the De-Jargonizer and Readability Scores

Orit Rabkin and Tzipora Rakedzon

Writing - Engaging - Distilling

19.1 Learning Outcomes

When writing, students often rely on jargon and a formal academic style—as a result they struggle to write for a general or non-scientific audience. After completing this exercise, students will be able to tailor their writing to non-specialists by adjusting their vocabulary and style. They will also be able to assess the suitability of their texts for different readers.

To help students learn these skills, we employ two free, online, user-friendly tools. The first tool rates vocabulary and jargon use; the second tool rates readability. These tools guide writers to the appropriate level of vocabulary, sentence length and passive voice for an audience. The exercise teaches students to communicate their work to different types of readers and stakeholders.

19.2 Teaching Context

We have used this exercise with undergraduate and graduate STEM graduate students. The exercise helps students prepare for future professional and scientific communication by addressing the most basic questions behind all texts and communication: who is my audience, and what language and style are appropriate to use when communicating with them? This activity helps students gain confidence writing about their projects in both academic and professional contexts. Students can work alone or in small groups.

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The exercise is easily adapted and implemented in any writing course or workshop as the length and time frame of the task are flexible. As described here, it uses student-written texts of 200–250 words each, but it can be adjusted to use slightly shorter or longer texts.

19.3 Overview of the Teaching Activity

Students write two brief summaries of their current research or project for two audiences—one from their field and another for a lay audience. They can do this before (or during) class.

In class, the instructor shows students the online vocabulary rating site, the De-Jargonizer. The instructor uploads or copy and pastes a text to the site and explains the three colour codes on the text. The black is for high-frequency (or everyday) words, yellow is for mid-frequency (or general academic) words and red is for rare (or technical jargon) words. The instructor sets a goal of two levels that will coincide with two different intended audiences, concentrating on problematic jargon. For text aimed at a highly specialized readership, we usually find over 5% jargon, while text for a lay audience has around 2% jargon. Students check their lay audience text against the metrics and adjust it if necessary. They can adjust by reducing the amount of jargon or adding definitions and explanations of key technical terms.

The instructor also explains the Flesch-Kincaid readability scale to the class. This scale grades a text in terms of school reading level from 1 to 22. It helps students understand if the text is junior high (level 6–8), high school (9–12), college level (12–15) or graduate school level (16 and above). The scale is based on features such as the word length, sentence length and use of passive voice. Students pass their rewritten exercise through the readability scale tool to score it. If the grade level is too high, students adjust their texts by changing passive sentences to active and dividing up long sentences. Then, they re-check their grade to see if they have reached their intended level.

19.4 Runsheet and Lesson Plan

It is preferable to begin with some basic, theoretical background. In our class, we talk about the audience and jargon before we introduce the exercise. In the table below, we suggest background readings and theory.

Students need computer access for this exercise. The exercise is explained in class, and the students write and check their work in class or for homework.

Instructor does…	**Students do…**	**Resources**
Establish background theory: what does it mean to appeal to different audiences (e.g., scientific vs lay)? How does "my story" change based on audience? Discuss word choice, jargon, and genre structure with the target audience in mind. With students, make a list of jargon words in the students' field. Make a second list of general words or terms that might replace them.	Read several example texts that compare scientific vs lay summaries. Encourage discussion, sharing their experiences with writing for different audiences (1). Discussion can include students identifying certain jargon unique to their audience.	A computer screen projected to show example texts. Student internet access. 30 min
Explain the writing exercise to students (2). Invite students to write their items. If this is done in class, circle around the room to answer students' questions while they write.	Students write two pieces, specifying the audience (usually this is expert and lay audiences). Writing can be done at home or in class.	Computers or tablets to write with. 60-120 min
Introduce the De-Jargonizer and the readability scale (2). Show the sites on a projected/ shared computer screen (4).	Give students time to "play" with the De-Jargonizer website and readability scale. See (3) for example texts students can use at this time.	Ability to share or project screen; texts (3). 15 min
Help students place their completed writing into the De-Jargonizer and readability scale tools. Discuss the results, comparing and contrasting results for different items (3).	Students look for differences, as well as strengths and weaknesses, in their own texts (5).	20 min
Invite students to share their results. Invite them to rewrite if the jargonizer reports the text is still not "general" enough or not "jargony" enough, or if their grade level was inappropriate for their audience.	Students edit their own work based on the results from the sites. They then submit their results on a shared document presented on the board.	Shared document and projection facility.

Rewrite can be done for homework. In our classes, the rewrites are submitted.	Discuss the word choices they made and what they changed in their text to better adapt to their audience. Discuss the differences between the two texts they wrote.	20 min
Extension Complete the peer-review assignment with specific instructions on how to evaluate and improve their peer's writing (6). The peer review allows students to give others feedback, so they understand there is an audience, a live reader, at the end of the process. Peer feedback helps the writer understand if they have communicated effectively with their audience.	*Extension* Students work silently following the handout without speaking to the writer because writers usually do not "get" to explain their materials to their readers. Students read their reviews and converse with the reviewer to ask questions and receive ideas for rewrites.	Peer review instruction handout (6). 30 min
Total duration in-class = 3 hours + 1 hour for extension activity		

Notes

(1) The time for this discussion depends on whether you are reminding students about their prior study or are teaching background theory for the first time. If you want to go beyond word choice and sentence complexity, you can discuss structural differences between types of writing as well. For example, lay summaries often begin with the bottom line, unlike academic abstracts which begin with the background and a case for importance (see Salita (2015) and Writing and Abstract resources)

(2) Students write a short summary of a research or project in their field. They are asked to explain twice: once to someone from their field (a colleague, a boss or an expert) and then again to someone not in their field (a stakeholder, a member of the public, a school group). Their instructions are to write a summary of 200–250 words. Participants are only allowed to use dictionaries without any references, books, other websites or previously written work. The idea is to get a 'raw' version of their knowledge of vocabulary and audience; therefore, we prefer to keep students away from material which might be tempting to copy

(3) Give students the chance to begin themselves, opening professional articles or professional blogs. It is important they choose the materials themselves. For

example, we use a definition of 'placebo' written for children by paediatricians (https://kids.frontiersin.org/) and compare Wikipedia's explanation. Guide students towards highly jargonized and lay texts. They can use the De-Jargonizer (Rakedzon et al., 2017) as well as a thesaurus

(4) The De-Jargonizer can be found at: http://scienceandpublic.com/. The Flesch-Kincaid readability scale is on the internet in several locations: e.g. https://readabilityformulas.com/free-readability-formula-tests.php

(5) After students complete their writing, present them with the problem of jargon and how the levels of vocabulary differ with the audience (i.e. we expect a higher percentage of jargon for expert audiences). Show examples—you could compare scientific journal articles to their popular science versions on online news sites

(6) It is important to stress to students that the peer review process which we are asking for is not about editing grammar. Reviewers should be asked to begin the process by focusing on audience and style using a detailed handout. On our handout (see Appendix), students are welcomed to offer generalized notes if grammar impedes readings

19.5 Top Tips for New Instructors

1. It is wonderful to see that once several communication principles and tools are placed before them, students can quickly begin 'playing' with the options, changing the language and content for each audience to produce convincing, impactful texts. They are surprised that tools which can help quantify language exist (such as the De-Jargonizer) and that these tools can help them precisely aim their language. They notice, for example, that the percentage of jargon is affected not only by the number of technical terms but also by their repetition in the text.
2. Keep in mind that all automated tools are to guide students in rating their level. All tools have limitations, and they require human judgement. For example, a student may have a high 'jargon' score (ten words in red) because they repeat a specific, highly jargonized word. If the student defined the term at the beginning (such as the name of an illness), they certainly can consider it more readable than the jargon scale suggests.
3. Before students write their summaries for the academic and lay audience, explain to them that it is best to start fresh with the lay audience summary, and not to try and adjust the academic audience summary. This is because the academic audience abstract will start with introductory material and include jargon, leading the students in the wrong direction. Each summary should be written 'from scratch'.
4. Students will learn that written communication requires flexibility and planning and that there are tools that can help them assess themselves. It may look as if writing is a creative process or perhaps just a technical process; however, it is, in fact, a process requiring organization, awareness of audience, multiple drafts, understanding of how grammar contributes to clarity and much more. It can be aimed, planned and adapted with the help of a few basic principles and tools.

5. Graduate students will need to communicate by choosing content and language to fit their audiences. Graduates who continue in academia need to publish in academic journals, but most science graduates do not end up in research, and they must develop the ability to communicate beyond academia. For example, scientists must be able to write persuasively to convince an employer to hire them or an investor that the small start-up or application idea will work. Therefore, the ability to analyse the communicative moment and goal, and translate that into suitable language, is crucial to science graduates' work and business success.

A. Appendix

Peer Review Guide for the Reviewer

Once you submit your own paper, your job is to be someone else's peer reviewer. Open the paper you are peer reviewing and write at the top clearly:**Reviewed by YOUR NAME**

As a reviewer, your task is to help the writer organize the work and consider their audience. BE KIND. ALWAYS BEGIN WITH POSITIVE COMMENTS. List things that the author has done well, and then address things that can be improved.

Comment briefly on each paragraph, using the three major criteria below. As you review, add comments or questions where the writer could improve the text.

1. **Audience:** Read the two paragraphs through at least once.
   (a) Is one written for an academic audience and one for a general audience?
   (b) Can you easily tell the difference?
   (c) Which keywords, verbs and phrases identify each writing? Underline these.
   (d) Place each paragraph in the De-Jargonizer. Which words are marked in red as highly jargonized? Does it confirm your sense of the difference between the two writings?
2. **Clarity:** Pay attention to sentence structure, noting that while *grammar is important you are NOT here to edit the grammar*.
   (a) How long are the sentences?
   (b) Can you identify subjects and verbs easily?
   (c) Are subjects and verbs close together?
   (d) Does the paper use nominalizations? Highlight them. Are they necessary? Are there some that can be turned into active verbs?
3. **Structure:**
   (a) Look for an introduction, clear aim of the research/clear claim.
   (b) Is the writing organized logically, telling the 'story' using signal words between the sentences and the paragraphs?

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Part IV

Practice Distilling

Statements of Critical Significance (SOCS) for Communicating Succinctly

20

E. Austin Leone, Kristy Daniel, Donald French, and Michael Clough

Distilling - Writing - Intent

20.1 Learning Outcomes

Statements of Critical Significance (SOCS) are short (maximum 30 words) statements that present important ideas from a piece or set of literature. The act of developing and articulating SOCS promotes analysis and understanding, critical thinking, and iterative writing behaviors.

In this exercise, students learn how to communicate three different types of SOCS:

- SOCS that distil the main ideas or important findings in an article
- SOCS that compare and contrast ideas across articles
- SOCS that describe useful methods or practical applications in articles

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Students can use these SOCS to demonstrate their understanding of key ideas in scientific literature. Development of SOCS also helps students craft papers, reports, and presentations.

The exercise described here is focused on helping students learn to extract critical ideas from a piece of written text.

20.2 Teaching Context

Many strategies exist for assisting students to condense and communicate the critical points found in literature. We adapted a teaching strategy (also called "Points of Most Significance" or "Statements of Crucial Significance") (Cossman, 1990; Daas, 2005) for post-secondary biology students. We have used the SOCS strategy in lecture courses that include reading of primary literature; in courses requiring students to engage in scientific writing; and in graduate research groups. It is important to explain to students why and how they can use SOCS—in our teaching we emphasize how the act of writing SOCS helps identify key ideas while also improving critical thinking and written communication.

There are three types of SOCS (Appendix 1):

- $SOCS_A$ (Statement Representing Substantive Content of the Reading) expresses one coherent idea (not a collection of ideas) capturing the substantive content (essence or spirit) of a single article.
- $SOCS_B$ (Statement Regarding the Relationship Between Substantive Content of Different Readings) relates common themes emerging from multiple readings. The relationships (comparison, contrast, similarities, etc.) between ideas, examples, and arguments presented in different readings should be pursued to make informative statements. This expresses one overarchering or substantiative ideas/trends across multiple papers.
- $SOCS_C$ (Statement Representing Implications or Practice) represents action-level thinking about what should be integrated in personal science practice. For example, this statement may identify a significant method useful in a student's research.

20.3 Overview of the Teaching Activity

In our activity, students first craft SOCS from a single selected reading ($SOCS_A$); then compare and contrast crucial points among readings ($SOCS_B$); and finally consider the implications of crucial ideas for your personal science practice ($SOCS_C$). This activity helps students analyze text and distil crucial points to support their own technical writing.

When introducing SOCS, we recommend using a readable and straightforward passage such as the provided example paper (Appendix 2). Our activity introduces students to SOCS; has them work collaboratively with instructor guidance to write example SOCS from a shared manuscript; and provides immediate formative feedback supporting students as they work.

20.4 Runsheet and Lesson Plan

Instructor does...	Students do...	Resources
Provide students with the example paper that they will use to practice crafting SOCS.	Read example paper in class (1).	Example paper (2) SOCS Instructions (Appendix A) 30 min
Introduce SOCS, including types and examples of each (3), required structure (4), and the value of SOCS.	Ask clarifying questions.	SOCS Instructions 20 min
Facilitate class collaboration, creating the first SOCS for the example paper (5). Start students working on a complete set of SOCS for the exemplar article. Support students during activity.	Brainstorm and create an initial SOCS (6). Then, have students work in groups to create 1-2 additional SOCS for the mini-journal article highlighting other critical ideas (7).	Example paper 45 min
Select a spokesperson from each group to share their work with and the class.	Share their SOCS and compare/contrast SOCS written by others.	Student-generated SOCS 15 min
Extension (30 + min) *Instructor:* Demonstrates how SOCS can be integrated into a lab report or manuscript (8). *Students:* Practice writing literature reviews and methods sections using SOCS.		
Total duration in-class = 110 min + 30+ min in-class or future extension.		

Notes

(1) Can be completed prior to or during class

(2) Instructors can choose any example reading for this activity. We selected the exemplar article because it was written so students could easily understand it. It also models a type of lab report our undergraduate students would write. See Appendix 2

(3) See Appendix 3. For an example of a set of SOCS from a different reading set, see Appendix 3

(4) SOCS are not summaries of what has been read, but rather the synthesis of significant ideas that emerge from reading. SOCS must be carefully written and thoroughly reviewed for clarity and sense (e.g., does the statement say what is intended, and will others understand it as you do). Each SOCS may not exceed 30 words (think of this as a tweet!). Always indicate the type of SOCS written (A, B, or C) and include the author's name(s); all types may not be necessary in each set. Ideas may be lost when significance and crucial connections (or citations) are omitted. Author names are not counted towards the 30 words

(5) Students struggle to distinguish SOCS from summary statements when first writing SOCS. When addressing the example reading in class, first have students brainstorm ideas that stand out as they read the article. For our provided reading, students may suggest: needing to be conscientious about how we disturb ecosystems; harvesting practices promoting diversity (such as uneven harvesting) lead to greener outcomes; girdling is an effective strategy for restoring forest biodiversity; and/or a defining biodiversity and what it entails for humans (although this last idea is a summary and not a crucial idea from the article). Next, have students decide which idea is most crucial and use it to create example SOCS. Write students' suggested statements on the board. Seek to write a single synthesis statement reflecting the crucial idea in a manner that does not necessitate reviewing the article. This statement should be one that could be inserted into a literature review or a methods section. Encourage students to consider the context of the idea and include needed specifics. See 6 for example SOCS

(6) Example SOCS from the article we assigned include: $SOCS_A$—Even-aged harvesting has caused Missouri riparian ecosystems to decline, whereas changing practices to uneven harvesting can prevent such decline. $SOCS_A$: In Missouri riparian ecosystems, uneven logging harvesting prevents native biodiversity loss to levels almost equal to unharvested areas, and this finding supports greener practices. $SOCS_C$: Using a "green" approach, such as girdling, when considering logging practices can help us take a conscientious approach to avoid unnecessarily disturbing our ecosystem. (Note: we did not include an example of a $SOCS_B$; $SOCS_B$ statements are ideas/trends across multiple articles)

(7) Instructors may choose how many SOCS students write (we suggest 3–6 SOCS per assigned reading set) and whether students create SOCS independently or in small groups

(8) After students are comfortable writing SOCS for the mini-journal article, we suggest demonstrating the value of SOCS for accurately identifying crucial ideas, promoting concise writing, and integrating into more lengthy writing

tasks. Then, assign students to read relevant literature, and submit the number and variety of SOCS you think are appropriate. Use students' SOCS to illustrate how pasting their SOCS into abstract, literature review, or methods sections of their document helps craft their narrative. For example, if a student is struggling to build a literature review, direct them to paste their $SOCS_A$ and $SOCS_B$ to logically present their review. $SOCS_C$ statements are useful in literature review or methods sections if a student identifies a previous methodology to critique or expand upon in their current study (Appendix 4)

20.5 Top Tips for New Instructors

1. Students often have experience annotating articles, but it is rare for them to examine readings in order to extract and express crucial ideas. Help students group ideas by like types and prioritize what is most critical from the reading. Explicitly work through the decision-making process with the students, and help them identify particular ideas as crucial (while others not). Then, have students practice transforming an idea into concise sentences while also including necessary details for context.
2. Students *will* struggle to write clear and tight SOCS; be prepared to remain supportive in the face of student frustration and negative comments. When students write $SOCS_A$ summarizing an article without identifying a clear crucial idea, ask guiding questions like: “What is the most crucial idea?”; “What is the second most crucial idea?”; “Why are these ideas crucial?”; and “If you read this SOCS in one year from now, how well would you understand the crucial idea without reading the whole paper again?”
3. Have students share their SOCS with others (who have and have not read the article(s)) to assess the crucial idea expressed.
4. Students can be protective of their writing. Provide constructive feedback on students' SOCS, especially early in the writing process.
5. Emphasize that writing is a learning and communication activity. Writing is often wrongly considered solely a communication activity. But writing, when taken seriously, promotes and reflects thinking (Zinsser, 1993, 2006)! Students will only slowly come to understand that their difficulties in writing are really difficulties in thinking and crafting clear logical statements that accurately expresses an idea. Effective writing requires placing yourself in the reader's mind and asking yourself whether your written message would be absolutely clear to someone who has not read the SOCS.

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An Infographic Is Worth a Thousand Words: Teaching Visual Communication in the Digital Age

21

Michael Buckholt and Jill Rulfs

Distilling - Storytelling - Organising

21.1 Learning Outcomes

Students often have difficulty focusing on a message in summarizing a research article, writing an abstract, or conveying the results of their laboratory work. They are often distracted by details and enticed by their love of technology to generate images. This exercise begins with simplifying the message and ends with design. After completing this exercise, students will be able to translate written text into a visual message. They will define the focus of their message; identify the data, statistics, and graphics to support that message; and create a visual product that communicates their message and informs and convinces the reader.

21.2 Teaching Context

We have used this activity in various undergraduate biology courses, generally with first- or second-year students. We tailor the information source and the purpose of the infographic to the students. For example, in a freshman seminar, students read simple research publications and present relevant findings in an infographic. In a nonmajor course, students use a textbook chapter as the foundation for their work. Students in an authentic research-based laboratory course can use the infographic to explain the outcomes of their research.

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All of the activities are tied together by having the students identify the essential messages, minimize the amount of text, and optimize the use of figures and graphics to convey the message.

21.3 Overview of the Teaching Activity

Depending on the context in which the activity is used, students may be assigned reading (a text or other publication) or a review of their laboratory notebook to be completed before class.

The lesson generally starts with having students look at a series of infographics, each for a given amount of time (2–3 min). The figure is removed, then students are asked to share the messages they can recall. They also identify other things they noted, such as color palettes, visual balance, text size and font use, organization, and flow. Using a scale of 1–10, they score the effectiveness of each infographic and explain the basis for their score.

Students are then given a set of sequential steps in the process and other things to think about (see Runsheet notes). Once they have completed the required steps, each person or team drafts a storyboard with general plans for the layout. The lesson can end here with each team using this foundation to design their infographic outside of class using a software program (e.g., Piktochart or VISME). Alternatively, infographic design can be completed or begun in an extended class period.

21.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Introduce the concept of an infographic (1). Give students a selection of infographics to look at for 2-3 minutes (in groups or alone). Remove infographics. Ask students to identify the infographics' essential messages.	Look at the infographics for 2-3 minutes. After the infographic pictures are removed, identify the essential messages they convey.	Handouts of infographics 5 min
Show infographics again. Ask students to score them for effectiveness. Discuss elements of the infographics that convey message.	Using a 1-10 scale, score each infographic. Identify other aspects of note (colour, balance, flow, organization)	Projected images of infographics 5 min

Explain the steps in creating an infographic, emphasise the order in which they should be done (2).		3 min
Ask students to begin planning their infographic, based on the information they need to convey (this is the material they reviewed before coming to class). Provide a list of minimum requirements (3).	Use the ordered steps presented by the instructor to identify and plan each part of the message, data, and layout for their infographic.	Method for students to record their progress. 15 min
Stop students and remind them that design comes last. Before proceeding, ask students: "Do you have everything you need to convey the message?" "Do you need to use everything you have planned so far to do the job?	Students continue to refine the message, the supporting data, and the overall layout.	2 min
Explain the concept of a storyboard (4). Provide an example if you would like to.	Using paper and pencil, sketch a storyboard laying out text, figures and adding annotations. Use the Canva tool if desired.	Canva Website 10 min
Provide questions to evaluate the content and layout of the storyboard (5).	Review their storyboard and respond to questions, making changes as necessary.	5 min
Review and show the kinds of tools available in a software package like Piktochart. May assign a final infographic as homework or allow time in class to work using a software package.	Create and submit a final infographic product. Students may wish to access things like font choice and colour emotion wheel sites (see websites).	Website links to infographics tools 30-60 min
Extension Final infographics submissions may be assigned for peer review. If you have chosen a specific rubric (6) these can be made available to students for use in their reviews.		30-60 min at home
Total duration in-class = 50min; 30-60 minutes for extension activity which may include peer review		

Notes

(1) A common definition is: infographics are graphic visual representations of information, data, or knowledge intended to present information quickly and clearly

(2) Steps are:
   (a) Tell a story (what's the message? what do you want to say?)
   (b) Decide on the data (what will best convey your message?)
   (c) Simplify (do you need everything you have identified?)
   (d) Design the layout (how much space should each item get?)
   (e) Create the graphs, charts, or figures (are they easy to interpret?)

(3) You can be as prescriptive and detailed as you like in defining the requirements. You may wish to use this opportunity to review copyright and fair use rules. Checklist items could include:
   (a) Main title
   (b) Subtitles or section headings (2–4)
   (c) Facts to be conveyed (1–5)
   (d) Graphs/charts for data presentation (1–2)
   (e) Other graphics related to the topic (drawings, illustrations, pictures)
   (f) Sources to be cited

(4) For our purposes, storyboards are hand-drawn sketches that define the layout of images and text, including annotations of details like color, text font and size, and use of empty space for emphasis and flow. They provide an opportunity (prior to final design) to visualize the organization, check the balance of text and images, optimize the flow, and ensure consistency of design parameters

(5) Useful review questions for storyboards:
   (a) Do the reader's eyes know where to go next?
   (b) Is the color appealing and consistent with your message?
   (c) Do the text and graphics support the correct emphasis?
   (d) Is the distribution of space, text, and graphics right?
   (e) Is the message effectively conveyed?

(6) There are a number of rubrics available on the internet that may be useful. Using a rubric helps restrict student critiques to the learning outcomes of the lesson and avoids personal preferences or comparisons

21.5 Top Tips for New Instructors

1. Today's digital natives are comfortable and happy with the use of bells and whistles available in lots of design software. This often distracts them from thinking about the message or story, as they gravitate to the cool images, interesting fonts, or backgrounds they might want to include. The use of a planning guide or checklist they must complete before moving on to storyboard or infographic design may help keep them on track.

2. The aha moments usually come when they realize that a well-chosen graph or illustration can replace a lot of text.
3. You may choose to delay introducing them to software tools like Canva or Piktochart until they have completed a worksheet or planning document where they have articulated in short sentences or bullet points the messages or information they want to convey.
4. The opening discussion and critique of example infographics may be used to generate a list of helpful hints for the class as a whole. Some students are much more tuned into design and balance than others. Some are more artistic or creative—they will see things their peers may not. Some will note inconsistencies in font size or design that others may miss. The opening discussion time is time well spent; generating a list on a board or flip chart may give students a focus for their own review. If students are working in teams, this is also an opportunity for the team members to see that different people have different things to contribute.
5. If you are using peer reviews, which can be a nice way to review and reinforce the objectives of the activity, we suggest removing student identifiers so authors and reviewers remain anonymous. This can also be an opportunity to explain the use of a rubric as a metric for final review before submission.
6. A simple but effective exercise in place of a rubric-based peer review is to have the authors of the infographic list three to five bullet points or brief "take home messages" they wanted the viewer to remember. You can then have the peer reviewers make a list of messages they took away. This is a quick way to assess both the effectiveness of the infographic and the ability of the authors to identify important focus points from their assigned text.
7. Over the last few years, there has been an explosion in the number of guides, software packages, videos, and other resources about infographics on the internet. We have included some links you may find helpful but make no claim that these are the best you can find. We are simply suggesting a few resources you and your students may find useful and fun.

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Website Links

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Piktochart (Infographic maker). (https://piktochart.com/formats/infographics/). *Accessed 29 Dec 2020*.

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Hooks and Headlines

22

Catriona Nguyen-Robertson, Linden Ashcroft, Jen Martin, and Michael Wheeler

Distilling - Engaging - Writing

22.1 Learning Outcomes

Scientists and science communicators need to capture their audience's attention to communicate scientific information. This activity encourages students to develop this skill by asking them to translate information from recently published scientific abstracts into a captivating and informative "hook", with an accompanying "headline".

After completing the exercise, students will understand the concept of a "hook" for opening a communication activity and grabbing an audience's attention. They will have practiced extracting key messages from scientific material and communicating them in an accessible, engaging way by creating their own hooks.

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22.2 Teaching Context

We use this activity to help research-active graduate students gain confidence in distilling complex scientific information and capturing the attention of a target audience. It was designed for face-to-face delivery but can easily be adapted to online teaching. Students create headlines and hooks based on abstracts of recently published scientific articles or own research.

Students practice reading and distilling scientific information and communicating it to people who have some scientific understanding and interest, but no expertise in field covered by the abstract. Students decide on how they would frame the story with an accurate and engaging hook and headline. It is up to the instructor to outline the target audience(s) for the activity. However, we find that an interdisciplinary audience who is interested in science reduces jargon usage and is an accurate reflection of the audiences that students will encounter in the workplace.

22.3 Overview of the Teaching Activity

In this exercise we familiarise students with some common "hook" techniques using examples from published abstracts and corresponding science news stories. We consider a "hook" to be the technique used by a writer to grab the attention of a reader at the start of their article and compel them to read on. Hook techniques include posing a question, tapping into the zeitgeist and opening an article with a mystery or startling assertion, as well as using humour, "punchy" language, relatable examples or analogies.

We then ask students to read an abstract from a recently published scientific paper and, in groups of three (or pairs for small classes), discuss potential headlines and hooks—a catchy opening sentence or particular storytelling angle—for a news story based on the paper.

We encourage students to consider: "Who am I communicating to?" and "How do I get them interested in this science?". These are key questions because they help to identify the main message from the abstract and the most appropriate and engaging way of delivering it.

Students then present their headline and hook to the class as a pitch. They receive feedback from classmates to further refine their hook, and we open up discussions around the different framing of science research in a peer-reviewed publication and a popular scientific news article. When possible, we also reveal the hooks and headlines used in real science news articles about the research, giving the students a chance to compare their approach with that of journalists.

22.4 Runsheet and Lesson Plan

It is important that the students share their ideas with each other and discuss different angles; you may need to adjust times in the lesson plan for them to do this.

Instructor does…	Students do…	Resources
Explain purpose and wider application of the exercise. Discuss what we mean by "hook". Introduce common strategies used in headlines and hooks of science news articles.	Propose ways that an article or news item can engage them at first encounter (i.e., what "hooks" them?)	Optional Slide deck (1) 5 min
Provide an exemplar scientific abstract (2). Invite students to discuss (i) how the abstract can be framed as a science news story and (ii) find a hook to engage a target audience.	Read the abstract and identify the key points. Discuss framing and hook-formation for the abstract. Consider target audience during this discussion.	Abstract 10 min
Show a published science news story which was written based on the exemplar abstract. *Optional* - Repeat with another abstract.	Comment on how the writer uses a hook and headline to engage the reader (4).	News story 5-10 min, depending on second abstract
Ask students to create their own headline and hooks for a news piece for a given scientific abstract (2,3)	In groups of three (or pairs for small classes), read their given abstract, develop an angle for a story, then create a hook and headline.	Abstract 15 min
Invite groups to present; use time limit of 1-2 min per pitch to incentivise and enforce brevity.	Students from each group pitch their story, including a headline and hook.	Timer 10+ min
Show students examples of news stories that were published based on the given abstracts. Facilitate discussion around the different strategies used by scientists and journalists to engage the audience.	Discuss strategies; compare their hooks with those used by journalists (5).	10 min
Extension After students pitch their headline and hook, student peers provide brief feedback to their classmates (6).		10+ min

Extension Students are supported to craft (and post) a Tweet around a particular scientific paper, presentation, their research, etc (7).	Twitter account 15 min
Extension/Homework Ask students to generate a hook and headline for their own story. Students synthesise a headline and one-sentence hook for their own research (or chosen topic if not research-active students) (8). They can workshop their ideas in pairs/small groups to ensure that their hooks capture an audience's attention.	10 min [or homework activity]
Total duration in-class = 60-70 min + 25+ minutes for extension activities	

Notes

(1) Slides provided (see Appendix 1) are optional to use and may be tailored to your specific task. When running this activity online, it helps to use slides to display exemplar abstracts for students to read and discuss. When working online, upload the abstracts as documents for students to read in breakout rooms

(2) Provide a number of recently published scientific abstracts and corresponding news articles based on the scientific paper (only the first few paragraphs need to be provided, since the focus is on the headline and hook). Ideally these would be abstracts that students have not yet read
Abstracts (and news stories) may be selected from within a scientific discipline, or from broader areas, depending on whether you want your students to focus on intra- or interdisciplinary communication. You can also consider whether you want students to read articles only from within their discipline or whether they will benefit from reading more widely

(3) Emphasise that students should avoid "clickbait" headlines and sensationalism. Hooks and headlines should capture attention while remaining informative and accurate. Students quickly start adopting puns, rhymes, jokes and more in their scientific hooks, making them clever, entertaining and captivating. This stimulates useful discussion around the balancing act of being engaging and accurate

(4) Common discussion points include whether the engaging aspect of the research is easily identified from the abstract, how accurate the news story hook and headline needs to be and possible other angles the writer could have taken

(5) Common discussion points include the differences between audiences of peer-reviewed articles and science news stories, whether hooks are a common part of scientific writing and the importance of writing clear and accessible abstracts

(6) There are multiple options for how peer feedback can be incorporated. In face-to-face teaching, brief written feedback using sticky notes can be provided by

students and collected by the teacher who delivers it to the appropriate group/person. Alternatively, if running this session online, feedback can be collected in the chat function of the online teaching platform

(7) Tweeting helps students learn to communicate science in succinct, engaging ways, as well as helping to expand their networks, especially given that social media platforms are increasingly being used to communicate and disseminate scientific information

(8) It works well to ask research-active students to create a headline and hook in a similar way for their own scientific research. Asked them to present a headline, as well as think about how they would “hook in” different audiences and stakeholders (e.g. politicians, funding bodies and the general public). Ask students why they would fund a grant/proposal if they were in the funder’s position. We have found that by asking this question early on, students adopt strategies based on their answers

22.5 Top Tips for New Instructors

1. Use recently published scientific abstracts (ideally within the last year) that have an accompanying news story. It can be helpful to browse *Science News*, *New Scientist* etc. for articles (see Website Links) and then search for corresponding abstracts in the primary literature (i.e. work backwards from news piece to abstract).
2. Note that we do not use journalists’ news pieces to show the “correct” way to frame the story or “best” hooks/headlines, but rather to facilitate discussion around the different approaches taken by journalists depending on their audience. In fact, we often find that the approaches taken by students are more engaging. This leads to a useful discussion about the fact that many journalists don’t have a background in science, and so a clear abstract is vital if your research is going to be shared more broadly.
3. It can be challenging at first for students to digest abstracts from scientific papers outside their field. With practice, however, they become better at identifying important information from abstracts and tend to work well together in teams to understand the content, particularly the key points, well enough to communicate it effectively. We don’t allow our students to Google unfamiliar terms, but rather encourage them to try and understand the story from the abstract. If students look up terms, they might also find the relevant news article, which ruins the activity. The instructor should have a good understanding of the abstracts so they can help the students.
4. Communicating science clearly is fundamental in scientific practice and an integral part of interdisciplinary collaboration. We therefore focus on the teamwork aspect of this activity, by encouraging students to help each other to understand the abstracts provided and workshop hook ideas.
5. This task also exposes students to real-world scientific writing, giving them insights on what to do or what not to do when writing about science.

6. We use popular science news articles in this activity, but you could use articles and headlines from mainstream media publications instead, if you want to explore communicating science to a wider audience.

Website Links

Example Sites to Search for News Stories

New Scientist. (https://www.newscientist.com/section/news/). *Accessed 27 Jan 2021*.
Science. (https://www.science.org/news/latest-news). *Accessed 27 Jan 2021*.
Science Daily. (https://www.sciencedaily.com/news/). *Accessed 27 Jan 2021*.
Science News. (https://www.sciencenews.org/). *Accessed 27 Jan 2021*.
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Poetry as a Device to Distil Science

23

Sam Illingworth

Distilling - Writing - Investigating

23.1 Learning Outcomes

Poetry is a powerful way of communicating scientific information and opening up debate about scientific research. By writing poetry about specific scientific topics, students can learn how to communicate their work in an engaging and accessible manner. After completing this exercise, students will be able to write a short poem about a specific scientific topic and will also have gained experience in providing constructive feedback to their classmates.

23.2 Teaching Context

I have used this exercise when teaching postgraduate science students about how to communicate their scientific research to different audiences and have taught it in universities across the world. It introduces students to new ways in which they can write about their research in an engaging and accessible manner and encourages students to seek the important ideas in a paper or project and express them succinctly. It also helps to remind them why they fell in love with their subject in the first instance.

This activity is suitable for all undergraduate and postgraduate students, but it works best with students who are working on a specific research question (e.g. dissertations or doctoral theses).

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23.3 Overview of the Teaching Activity

This activity begins by asking students to read some examples of scientific poems (I usually use my own here, as they are published freely on my website and are thus free from copyright). The students then work in pairs to reflect on what they did and did not like about these poems and to consider the science that the poems were trying to communicate. These thoughts are then shared more widely as part of a whole class discussion, the purpose of which is to break down the stigma of 'analysing' poetry.

The students are then introduced to a selection of different poetic forms, which they will later use to write poems about their own scientific topic. A short writing warm-up is then used, in which the students write list poems about various subjects, following which the students are asked to pick a poetic form and draft a poem that aims to communicate their chosen topic to a specific audience (usually the other students in the room). After working on their drafts, the students provide feedback to each other in pairs and then return to edit their poems based on this feedback.

At the end of the session the students are invited to share any of their poems and to continue with the writing and editing process outside of the classroom.

23.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Read a science exemplar poem (1)	Whole class discussion of the poem (2)	Exemplar poem 5 min
Hand out science exemplar poems (3) Facilitate class discussion	Read poems and discuss in pairs (4) Discuss poems as a class (5)	Exemplar poems 10 min
Introduce poetic forms (6)	Consider which forms they might like to use	Internet access 10 min
Introduce list poems (7)	Write list poems	Writing material 10 min

Instruct students to write their own poems (8)	Write poems based on a chosen scientific topic	Writing material 15 min
Facilitate feedback (9)	Work in pairs to provide constructive feedback on drafts of poems	 10 min
Instruct students to edit their poems based on feedback (10)	Edit poems based on feedback	Writing material 10 min
Facilitate poetry sharing (11)	Share poems with whole class	 10 min
Extension - Introduce students to the *Consilience* journal (12).		Internet access 15 min
Total duration in-class = 80 minutes + 15 minutes for extension		

Notes

(1) An excellent example to use here is 'When I heard the Learn'd Astronomer' by Walt Whitman, which is available for free via the Poetry Foundation's website (see link below).

(2) This whole class discussion should not be overly analytical, but rather should serve to ask the students what they liked (or disliked) about the poem and why they felt this way.

(3) A wide selection (200+) of science poems can be found (and used) for free via my blog 'The Poetry of Science' (see link below). Alternatively, the Poetry Foundation's website has a large stock of poems that can be used; just search for the word 'Science'.

(4) In these discussions, students should be encouraged to discuss what it was that they did or did not like about the poem, and the extent to which they thought the science was communicated. Did the poem make them want to find out more about the research in question? Was it accessible in its use of language? Is there anything that they would have changed?

(5) In this whole class discussion, ask the students to share specific poems or passages that they thought were effective at communicating an aspect of a scientific topic. What was it about that passage that they liked, and how did it convey information or elicit further dialogue?

(6) Use the 'Shadow Poetry' website (see link below) to introduce two or three different poetic forms to the students. I recommend using the haiku, nonet, and kyrielle. Introducing specific poetic forms to the students helps to provide them

with a starting point for structuring their poem, as for some students being asked to simply 'write a poem' can be daunting.

(7) Get the students to warm up for their poetry writing by asking them to write list poems related to various topics. These work best by setting the students one minute to list as many things as they can about the chosen topic. These lists can include thoughts, feelings, and abstract concepts, as well as objects. Suitable topics include: 'this room', 'this city / town', 'this university', and 'science'. Students can also share these poems with the class if they like.

(8) Ask the students to think about one of the poetic forms that you have introduced them to and to pick one that they think will help to convey their chosen scientific topic. For example, if they are writing about the disappearance of sea ice, then the nonet might work well, as it creates a visual image of gradual retreat. When the students are working on their poems, be present in the room, and offer assistance to any student that looks as though they need help. You might also consider writing your own science poem during this time.

(9) Make sure to outline to the students what helpful and constructive feedback looks like, and to be respectful and courteous to the work of others.

(10) Remind the students that editing is essential to ensure that the poems work for their intended audience (who in this instance have very helpfully provided feedback to the poet).

(11) Invite students to share their poems (finished or otherwise), but don't force them to do so. Creating a supportive environment will make them more likely to want to share their work. End the session by encouraging the students to continue to edit their poems beyond the classroom and to share their work with each other, maybe via your institute's online learning management system (i.e., Blackboard, Moodle, etc.)

(12) *Consilience* is the world's first peer-reviewed science and poetry journal. Ask the students to browse the website (see link below), to pick some science poems that they enjoy, and to also consider submitting their own work.

23.5 Top Tips for New Instructors

1. This exercise works best when students have their own research project that they are working on. However, if you want to run it with an undergraduate class, then pick a peer-reviewed scientific article, and ask the students to read it in advance of the class. They can then all write poems about this specific scientific topic.
2. If students want to write poems that do not conform to a traditional poetic form, then they should be allowed to do so. Using specific form and metre is only recommended because it provides scaffolding to those students who are unsure of how to structure their writing. However, if a student wants to write something in free verse (or even make up their own poetic form), then this should be encouraged.

Further Reading

Students wanting to find out more about the relationship between science and poetry, and how it can be used to develop dialogue between different audiences might wish to read the following research articles:

Illingworth, S. (2016). Are scientific abstracts written in poetic verse an effective representation of the underlying research? *F1000Research*, *5* (91).

Illingworth, S. (2020). "This bookmark gauges the depths of the human": how poetry can help to personalise climate change. *Geoscience Communication, 3*(1), 35–47.

Illingworth, S., & Jack, K. (2018). Rhyme and reason-using poetry to talk to underserved audiences about environmental change. *Climate Risk Management, 19*, 120–129.

Website Links

Illingworth S (ed) (2022) Consilience. (https://www.consilience-journal.com). *Accessed 27 Jan 2022*.

Illingworth S (2022) The poetry of science. (https://thepoetryofscience.scienceblog.com). *Accessed 27 Jan 2022*.

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Shadow Poetry (2022) Shadow poetry. (http://www.shadowpoetry.com/). *Accessed 27 Jan 2022*.

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Put the Slides to One Side: Replacing Static Slides with a Prop 24

Alice Motion, Tom Gordon, and Siegbert Schmid

Distilling - Engaging - Intent

24.1 Learning Outcomes

Slide decks are a near-ubiquitous feature of oral presentations, but they are not always the most appropriate tool to aid communication. *Showing* science through demonstrations that make use of props, models or interactive experiments requires students to think differently about how they communicate science and enhances their understanding of concepts and theories.

This activity will help student think creatively about the tools and techniques they use to communicate science and shift their reliance on traditional slide deck presentations to more active forms of science communication. By building their own prop, model or demonstration, students will develop their science communication skills and develop a more holistic understanding of scientific concept by aligning theoretical knowledge with more practical demonstrations. Students will learn how to show science through experiments, or to create their own props as demonstrations of scientific concepts and theories, as models to communicate or illustrate scientific concepts.

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24.2 Teaching Context

We have used parts of this activity with students who are preparing for science communication competitions, taking science communication classes, delivering school outreach programmes or working as undergraduate demonstrators.

Sharing best practice examples of prop use or demonstrations is an important precursor to this activity. While we aim to perform our own demonstrations for students and think this leads to the best outcomes, videos of demonstrations can also be shared with students in advance of this activity.

This activity is useful for science students of all levels and can be helpful as part of a scaffolded activity for students involved in public outreach events or science festivals. It can also be used as an exercise to embolden students to try a different style of presentation within a research or video assessment context.

24.3 Overview of the Teaching Activity

This activity aims to show students that if a picture is worth a thousand words, then a 3D prop can be worth even more!

The activity begins by encouraging students to think about alternatives to PowerPoint slides for effective oral science communication. Students are next encouraged to consider the elements necessary to ensure that a prop, model or demonstration is an effective piece of science communication. Together the class develop a rubric based on the elements emerging from the discussion and scaffolding from the instructor. The students then each create a short presentation that includes a prop, model or demonstration in place of slides which are peer-assessed according to the class rubric.

Resources and tools are available on the SCOPE research group website (see Resources section below).

24.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Lead the class in a discussion, encouraging them to think about alternatives to PowerPoint presentations when communicating science. Help students access the word cloud software	Work in small groups to brainstorm different ways to communicate science. Share ideas to create a word cloud.	Appendix 1 Instructor Notes Part 1 Interactive polling and word cloud software (e.g. Mentimeter)
		15 mins

From the examples proposed, draw out concepts proximal to props, models, and demonstrations. Perform a piece of science communication using a prop, model, or demonstration for the class OR show the class a video example of the above (1).	Watch the demonstration or video	Appendix 1 Part 2 Instructor Notes 10 mins
Ask students to consider the elements necessary to ensure that this mode of communication is effective.	Working in groups, write down the elements necessary for effective science communication using props, models, or demonstrations.	Appendix 1 Part 3 Instructor Notes 10 min
Lead a class discussion where students share their rubric suggestions. Weave student suggestions together into a class rubric that will be used to assess student presentations (2).	Contribute suggestions to the discussion and assist the instructor in building a class rubric.	Appendix 1 Instructor Notes Part 3 Appendix 2 Example Rubric Tool (e.g., Google Sheets) to create a 'live' Class Rubric. 15 min
Sets students the challenge of creating their own demonstration using an experiment, model, or prop to be assessed using the Class Rubric (3-6).		Appendix 1 Instructor Notes 10 min
Homework (240 min): Students plan, test and prepare their demonstration using a model, prop, or experiment on a chosen science topic with careful consideration of safety. Students also start completing a worksheet (Appendix 3, Part 1) to guide them in the creation of their demonstration. A later part of the worksheet (Part 2) can be modified to include the class rubric so students can address the marking criteria as they plan their demonstration.		

Facilitate student presentations and provide students with a tool (online works best) to peer-mark the presentations of others (7). At the close of the session, reveal marks and the 'winning' presentation(s). To close the session, ask students to finish the worksheet (started as part of their homework) by completing a reflection (8).	Present demonstration to peers and submit a short reflection on their demonstration (2).	Appendix 1 Instructor Notes Appendix 3 Worksheet Part 3 ~60 min depending on cohort size (with large classes parallel marking sessions could be instigated).
Total duration in-class = 60 min taught lesson + class presentation time and 240 min of time outside of class. This exercise is designed to take place over two 60 min classes with 240 min of coursework conducted outside of class.		

Notes

(1) Alternatively, colleagues or senior students from relevant science disciplines could be invited to share models, props or demonstrations with the class
(2) An exemplar rubric can be found in Appendix 2 and used to guide class discussion as necessary. Ensure that considerations relating to health and safety are included in the rubric
(3) Encourage students to avoid overengineering their demonstration. Remind them that often, simple demonstrations are better
(4) Depending on the size of your class and the amount of time available to mark presentations, students can create their presentations individually or as groups
(5) Consider the length of time that students should present for in this task. We recommend 1.5–3 min and certainly no longer than 5 min per demonstration
(6) Depending on your classroom context, you could assign the same topic for each presentation or provide a selection of pertinent topics. Alternatively, students can choose their own topic. For more junior students, we recommend providing topics. More senior students can be encouraged to choose their own topic and provide the rationale for their decision
(7) Consider recording the presentations and featuring good examples on the course, department or university website
(8) The reflection should focus on what students learnt through the completion of their demonstration, focusing on principles, concepts, methods and skills that are transferable across different contexts

24.5 Top Tips for New Instructors

1. Showing students your own demonstration, prop or model is an effective way to build rapport with your class and to openly discuss things that you find challenging. However, if you are short on time or don't feel confident to model a demonstration to your class, the video resources provided are a great substitute. You can of course also find examples that are more relevant to your disciplinary context.
2. This exercise can be used to express the importance of practical or creative communication as we support audiences with different accessibility requirements.
3. This exercise also empowers students who do not excel at traditional PowerPoint presentations.

Website Link

Mentimeter word cloud. (https://www.mentimeter.com/features/word-cloud). *Accessed 1 Jan 2022*.

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Part V

Practice Speaking

25 Usability Testing Your Writing: Using the Think Aloud Protocol to Get Constructive Reader Feedback

Michelle Riedlinger and Glen Thomas

Speaking - Engaging - Writing

25.1 Learning Outcomes

Students often have difficulty giving constructive feedback to others on their writing. They can also struggle to take and apply constructive reader feedback. This activity introduces students to the Think Aloud Protocol, a tool for giving and obtaining feedback in a productive way. By the end of this activity, students will be able to confidently give feedback to others on their writing. The activity also helps students reframe how and why feedback from others is useful. It helps students appreciate reader engagement with their written work, as writers can see how reader feedback helps them improve their writing.

In professional research situations, the ability to give constructive feedback to others on written work is essential. The feedback process can be thought of as a conversation between readers (collaborators, peer reviewers, editors, etc.) and writers. Writers often need to address reader feedback through the review process, so they need to be able to articulate how they have done this.

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25.2 Teaching Context

We have used this activity to help undergraduate and postgraduate students rework their draft research papers, industry reports, and research posters. The Website Links section contains more detail on using the Think Aloud Protocol with student readers as a writing usability testing tool. The activity can be used for students at any level of education.

A focus on writing "correctness" at school and university means that many students view feedback from readers as part of "assessment," rather than as a valuable opportunity to reflect on and improve their skills as writers. Through this usability testing technique, students learn that giving content feedback and "editing" the work of others are different tasks requiring different skills. This technique encourages students to take control of their own revising process rather than passively accepting or rejecting feedback from others.

The activity prompts constructive conversations where readers help writers identify writers' strengths and problem areas. It can be used for any science communication writing task, such as for students who are preparing research papers, posters, press releases, or grant proposals.

The activity can be done in 1 h, with students reworking their drafts at home, or in a longer 2 or 3-h workshop, or in two workshops (pre-and post-rewriting of a draft document). We have taught the Think Aloud Protocol online and in person.

25.3 Overview of the Teaching Activity

The first part of this activity introduces students to the Think Aloud Protocol. We start by explaining and then modelling the technique. One Instructor will bring two copies of something that they have written to class, one copy for the writer and one for the reader. The second instructor will read the draft aloud and comment on what they are thinking as they read. This reader will stop when a thought strikes them, or at the end of each sentence or two to summarize what they are getting from the text. If something makes them "stop" as they read, they describe what they are thinking out loud. As the reader reads, the writer will make written notes on their copy of the draft as to what they might do to improve their work. The reader's experience of the text is crucial to emphasize with this activity, rather than readers seeking to find the "right" answers. The writer does not respond to the reader by explaining or justifying their content choices. They quietly take notes as their reader reads. The reader also comments on what they like about the writing, what is working well for them.

Each student brings two drafts of their written work to class for this activity. Students practice this technique in pairs or groups of three by swapping drafts. One student reads the work of another student out loud and stops whenever a thought strikes them. If students are in groups of three, then two students read the work of the third student writer out loud, alternating each sentence and discussing their understanding of the content while the writer takes notes. In all cases, the writer is a "fly on the wall" listening to their readers' conversation.

Instructors should encourage readers to let their writers know when they are doing things well. Students swap drafts until all writers have had feedback on their written work. At the end of this activity, the instructor facilitates a class discussion to better understand how their students experience this usability testing technique and to consolidate students' learning.

During this post-activity discussion, instructors can help students identify patterns in reading and writing practices that assist them with their text revision. Students then revise and edit their drafts at home or in class. They submit their final version along with a reflection on what they changed or did not change after this usability testing activity. The reflection component can be assessed.

25.4 Runsheet and Lesson Plan

In this lesson plan, the students' activity is a draft research article, but the plan and notes broadly apply to any other written communication. It is important for students to share their ideas with each other before and after the activity, so you will need to adjust the time in the runsheet for them to do this in some way.

Instructor does…	Students do…	Resources
Explain the purpose and wider application of the activity. Ask the students what their experience has been when getting feedback on their writing. What kind of feedback do they get? (1). Instructor writes up this feedback on the board then identifies patterns (2).	Students contribute to a discussion about feedback.	Whiteboard. 10 min
Explain the Think Aloud Protocol as a usability technique using instruction slides (3).		Instruction slides 5 min
Model the Think Aloud Protocol for students	Listen and contribute as appropriate	Projected screen for instructor (4) 10 min

Ask students to read each other's work using the Think Aloud Protocol.		Students' drafts of their written work (6) 20-30 min
Give students a few minutes to consider the feedback and to write some notes. Then ask them to share the feedback they gave and received in a class discussion (7).	*Extension* Students formally present their thoughts.	10 min
Ask students to revise their draft based on the feedback they have provided.	Revise draft (8).	Students revise drafts on computers. 20 min
Ask students to write a short reflection on what they changed or didn't change after this exercise (9).	Share in small groups/pairs. Report back to class.	10 min
Total duration in-class = Minimum 50 min but can be up to 3 hours or two workshops each of ~2 hours. Time depends on size of class and length of drafts.		

Notes

(1) The Website Resources section include useful resources about the Think Aloud Protocol to help instructors prepare for the discussion.

(2) Students may be accustomed to pointing to "surface level" issues associated with spelling, grammar, and punctuation. This activity provides instructors with a good opportunity to talk with students about more substantive writing issues that active readers identify.

(3) We have developed some information slides to assist instructors when explaining the Think Aloud Protocol (Appendix 1).

(4) The Think Aloud Protocol can be modelled with two instructors, or a single instructor can show some draft text on a screen, read each sentence aloud, and ask students to tell you what they are thinking as they read. Write notes on the projected text.

(5) If you see that pairs of students have finished, organize for them to swap pairs and repeat the activity with a different reader and writer.

(6) If students are doing this activity online or using computers, use Microsoft Word and teach them how to use the "Comments" function in Word, rather than the

Track Changes function. This will encourage them to take notes rather than edit the text directly and allow for better reflection.

(7) If time is short, ask each student to contribute one piece of feedback that they gave or received that they think is important to consider.

(8) Circulate in the class to answer student questions about what to do with the feedback. Make it clear that addressing the feedback is optional, but students will need to consider each comment and how they might respond.

(9) Depending on available time, this reflection can happen in or outside of the workshop and can be incorporated as part of the unit assessment. Instructors could prompt students to reflect on the following:
   (a) Where did your readers get the most confused?
   (b) What changes did you make after this review? Why?
   (c) What suggestions for changes did you ignore? Why?
   (d) Did this exercise help you understand where (and why) readers of your draft got confused? If so, why? If not, why not?
   (e) What other changes did you make based on thinking between the draft and final versions?

25.5 Top Tips for New Instructors

1. As the reader, students may look for the “right/wrong” answer or attempt a “fix” for the author. Encourage them to experience a draft text as one individual reader—this can be challenging for them. It is important to reiterate that they can express uncertainty if they are not sure of a correct spelling or grammatical construction. It is up to the writer to consider this feedback and decide what to do about it.
2. Encourage students to be kind to one another—novice assessors and reviewers are usually the most brutal, so helping students set the right “critical friend” tone is important.
3. Encourage readers to stop at the end of a couple of words, or after each sentence. Remind them to stop whenever a thought strikes them. Monitor this as you move around the room.
4. Encourage student readers to report what is going on in their minds as they read, and to report what they are understanding or what they are having difficulty with. Model what good Think Aloud feedback looks like. For example, instead of saying, “no focus,” a reader might say, “Okay. I’m through the first paragraph, but I can’t really say what you are going to focus on next. I can’t tell if it is increased viral activity generally or a decline in security protocols. I think you are going to talk about. . .” Or, instead of saying, “repetitive,” a reader could say, “I think you already said this in paragraph 2 when you talked about X. If there is something new then I’m missing it.”
5. Encourage readers to report moments when they think they are getting the gist of what is written—and summarize what they are reading in their own words. For

example, "Yes, I see that. The 'genetic analysis' is looking at the interaction of a bunch of genes rather than one gene in particular."

6. Tell readers that if they notice what seem to be "errors" in spelling and grammar, they could point out the degree to which these are distracting them from understanding the text, e.g., I notice that "does not show" comes after "supervised analyses." I am thinking that should be "did not show" because "analyses" is a plural noun, but it is not stopping me from understanding. Or "I've lost this sentence because I thought it was ended. Now I see a comma so I'm going back to re-read it."
7. Explain to writers that if something makes their reader stop, then it is worthy of reviewing to improve the draft.
8. Student writers often strike problems when they come to revise their work. They may need to go home and reflect on the feedback before revising. It is essential to include a reflection as part of this activity to encourage students to consider each piece of feedback and what they might do with it.

Website Links

A useful article demonstrating the usefulness of the Think Aloud Protocol for collecting reliable information on thought processes. (https://psycnet.apa.org/record/2010-23810-001?doi=1). *Accessed 21 Jan 2021*.

A useful article with some practical examples of useful Think Aloud feedback. (https://link.springer.com/article/10.1007/s40037-018-0492-z). *Accessed 21 Jan 2021*.

A useful research article on using the Think Aloud Protocol to help writers anticipate readers' needs. (https://journals.sagepub.com/doi/pdf/10.1177/0741088392009002001). *Accessed 21 Jan 2021*.

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Show and Speak with Compelling Graphs and Diagrams

26

Jenni Metcalfe and Toss Gascoigne

Speaking - Organising - Engaging

26.1 Learning Outcomes

After completing this exercise, students will know how to organize their data or ideas into diagrams or graphs that will engage their audiences. They will feel more skilled and confident at presenting and explaining these to different audiences. As well as explaining the graphs and diagrams, they will practice asking and answering questions.

26.2 Teaching Context

This exercise is part of our Presenting Science workshop, which we have conducted for scientists in 25 different countries. This exercise brings together a number of skills we discuss over the day when running a regular workshop:

- Sketching a simple, clear diagram, or graph.
- Explaining and discussing their graph or diagram to the audience (includes voice, stance, gestures).
- Techniques to use when answering questions.

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Participants explain their graph or diagram and answer questions from the audience. They are given feedback on their graph or diagram, how they explained it, and how they answered questions.

This graph or diagram can then be redrawn more professionally (e.g., using PowerPoint) and incorporated into a real presentation (Youknovsky and Bowers 2020).

26.3 Overview of the Teaching Activity

Students use a large sheet of paper (A1) and colored markers to sketch a graph or diagram, usually to illustrate some aspects of their research. They then stand in front of the audience and explain their graph or diagram in one minute.

After presenting their item, each student then takes three questions from the other participants.

At the end of the session, the instructor provides feedback about the presentation and the whole class collaborates to construct a set of guidelines about what an informative graph or diagram includes.

26.4 Runsheet and Lesson Plan

The following lesson plan is part of our 1-day presentation skills workshop. Participants in the full workshop are given a comprehensive booklet on “Presenting Science,” and this covers three aspects of presenting: Content, Style, and Visuals. (These booklets can be purchased from Econnect.) The lesson plan outlined below is about 20% of the full workshop.

This session reinforces the usefulness of clear diagrams in presenting research, especially data or complex ideas. It emphasizes the importance of maintaining an effective presentation style in front of the audience when discussing graphs (including eye contact and an ability to answer questions).

We sometimes extend this session after the exercise below for a more in-depth discussion of tips for preparing and presenting visual aids.

While the exercise uses flip-chart paper this is for demonstration purposes only. The points we make about design apply equally well to PowerPoint.

Instructor does…	Students do…	Resources
Instructor leads a discussion on how to ask and how to answer questions.	Participate in the discussion.	Tips (1) (2) 10 mins
Instructor explains the exercise and gives each student a large sheet of paper (A1) and pens. Instructor gives the students has 30 minutes to sketch a graph/diagram.	Listen and ask questions. Decide on the topic for their graph and sketch it (3).	Paper and markers (4) 50 min
Once everyone has completed their drawing (5), facilitate presentations. Each student comes to the front, explains their graph in one minute,	Each student stands in turn in front of the audience. The diagram is fixed to a whiteboard.	Method to attach the paper to a whiteboard
then takes three questions from the rest of the group (6). After each presentation, lead a short discussion providing feedback (7).	They have one minute to explain it before taking questions (8).	70 min (for 10 students)
Lead a reflective discussion in which everyone collaborates to define the best practices for drawing graphs and diagrams (9).	Offer suggestions from what they have just learned and errors or good practice they have encountered previously.	Whiteboard 10 min
Extension Instructor and students discuss 'Metcalfe's 5 rules for visual aids' (10).		20 min
Total duration in-class = 120 min + 20 minutes for extension activity. This timing is based on 10 students and 7 minutes per student to present, take questions and receive feedback		

Notes

(1) Students may be shy about asking questions, so it is good to have an initial discussion about why people ask questions. This discussion will come up with the following reasons:
  - (a) Clarify a point
  - (b) Seek additional information
  - (c) Show they are present at a meeting
  - (d) Show how much they know about a topic
  - (e) Debate with the questioner
  - (f) Check on the questioner's knowledge
  - (g) Disagree with the questioner

The key point from this discussion is that people ask questions for a variety of reasons; it is important to keep this in mind when answering questions. The instructor should emphasize the importance and ease of asking questions related to the first two dot points (this helps students ask their own questions later in the exercise).

(2) The initial discussion can then move to tips for answering questions. This can be summarized on a whiteboard as a list of dos and don'ts. For example:
Do
   (a) Be brief.
   (b) Be polite.
   (c) Be honest when you don't know the answer.
   (d) Be prepared to clarify the question and repeat it back to the audience, so everyone has heard it and is clear about what you are being asked.
   (e) Keep in mind that the question session is an opportunity for the whole audience to get more information and clarification while also sharing ideas. So, be prepared to defer a question to later if it (a) asks you to repeat a part of your talk, (b) asks for too much information, (c) is off the main topic, or (d) is looking for a prolonged public debate.

Don't
(a) Get angry.
(b) Get into a debate.
(c) Get into a conversation with one person.
(d) Allow anyone to take over your question time (e.g., your supervisor).
(e) Pretend to know the answer when you don't.

(3) Sometimes students can't think of something to draw, so it is a good idea before this session to ask them to prepare. They can consider a presentation they might need to give where they will use visuals to present data or explain a complex idea. It does not have to be about science or their research—we have had students explaining the rules of netball.
(4) Sometimes students start but then want to redo their drawing, so have extra paper available. Have a variety of colored marker pens, mostly blue and black, and about 2 per student.
(5) Students will finish their drawings at different times. Encourage early finishers to review their drawings while the others finish.
(6) If possible, record each student's presentation. If there is time, you can play these back and provide feedback. But if time is short, give the recordings to each student, so they can look back and learn from their own performances.
(7) The timing of this section depends on how many students you have. For each student, allow 1 min for presenting; 3 min for questions and 3 min for feedback and change over to the next student (total 7 min/student). Feedback should address the following topics:

(a) *Their graph and diagram*
   (I) Does it explain a point clearly?
   (II) Is it legible to all people in the audience?
   (III) Do the instructors have any suggestions and comments (e.g., on use of colors, use of legends)?
   (IV) Are labels on the graph written in upper and lower case (rather than all CAPS, which is harder to read)?
   (V) Did it convey one clear idea?
(b) *Their presentation style*
   (I) Did they look at the audience, or turn their back on them while explaining their graph?
   (II) Was their explanation clear to the audience?
   (III) Did they look around the audience when answering questions, or just at the person asking the questions?
(c) *Their answers to questions (consider the dos and don'ts above)*

(8) It is a good idea to get students to ask at least two questions of another presenter. This means all students get practice asking and answering questions.
(9) These can be surprisingly simple things that students often do not understand or do in their daily practice (e.g., label both axes of a graph). This is an opportunity to point out errors that you have seen from previous students in exams or assignments—this helps your current students avoid the same traps.
(10) Metcalfe's five rules for visual aids can be used to discuss the principles for effective use of visual aids. Here are the five rules, with points under each to assist the instructor to discuss them.

Rule 1. You, as the Presenter, Are the Most Important Visual Aid

- Showing text on screen and then reading it aloud irritates your audience (they can read faster than you talk). Reading is distracting. It blunts your natural enthusiasm and cuts your eye contact with the audience.
- The way you present your information determines whether the audience decides to listen and learn. Speakers can have great ideas, but if they are not well presented, audiences stop listening.

Rule 2. Less Is More

- Minimize the number of slides. Too many slides are overwhelming and mean you may run overtime.
- You do not have to have slides showing continuously. Consider using them only in critical sections of your talk where they will have more impact.
- One slide, one idea. Do not cram multiple ideas into one slide.
- If you are using text, try for no more than six words across and six lines down.
- No slides are better than bad slides.

Rule 3. A Picture Tells a Thousand Words

- Diagrams and pictures have more impact than lots of words. Images help explain complex ideas.

- Use graphs, not tables. Make any diagrams clear, legible, and easily understood. Use a minimum font size of 28.

Rule 4. Three Dimensions Are Better than Two
- Sometimes real objects can help you tell a story, especially with small groups. Bring in real samples of your work.
- BUT do not pass things around while you are speaking. Show the object, but only allow people to look more closely when your presentation has ended. Alternatively, stop speaking until everyone has had a look.

Rule 5. Variety Is the Spice of Life
- Try to build variety into your presentation: colors, photos, and diagrams. But in PowerPoint, do not overuse sound effects or whooshing slides.
- Give the audience a break. Do not use PowerPoint slides all the way. Blackout the screen by using the "B" button on your computer keyboard—the audience will automatically swing their attention back to you, the presenter. Return to your presentation by pressing "B" again, or the mouse, or the return key.

26.5 Top Tips for New Instructors

1. This session runs best with small groups of about ten people as a practical exercise. It can work with larger groups, but you will need to limit the demonstration exercise to about six people instead of the whole group.
2. This session should be practical. Give examples and advice, discuss issues, and then give plenty of opportunities for participants to practice skills.
3. Some participants find public speaking a challenge, but you can use humor to lighten the atmosphere.
4. We recommend running sessions like this with a colleague, whenever possible. It provides variety in the style and voice of the instructor, and it makes the teaching less stressful. A technique that can work well is for instructor A to publicly clarify something with instructor B: "so when you said everyone has to draw a diagram or graph, does it have to be about research they are doing?" Having two presenters also means that while one instructor is videotaping participants the other can be giving feedback.
5. Make sure you have plenty of A1-sized flip-chart paper and colored markers for the exercise. Bring blue-tac or tape to attach each person's drawing to the whiteboard for presentation.

Reference

Youknovsky, A., & Bowers, J. (2020). *Sell your research, public speaking for scientists*. Springer. ISBN 978-3-030-34180-0.

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Using Sentence Frames and Question Cards to Scaffold Discourse and Argumentation in Science 27

Kelly Moore and Holly Garrett Anthony

Speaking - Listening - Conversation

27.1 Learning Outcomes

Students are often uncomfortable openly disagreeing with their peers and asking challenging questions of each other. In the practice of argumentation—which is meant to clarify and refine scientific explanations—these types of exchanges are essential. Argument provides a means for identifying the strengths and weaknesses within an explanation (National Research Council, 2012). Scientists must regularly defend their reasoning using evidence from empirical investigations, and they are continually refining their own understandings as they are challenged and critiqued by peers. The authentic practice of argumentation should begin in the science classroom. In a classroom, two things are needed to productively promote challenging discourse: a safe environment and appropriate scaffolds for student interactions (Windschitl et al., 2018). This exercise provides scaffolding for student collaboration and argumentation in the form of sentence frames and question cards to help students develop self-efficacy and proficiency in analyzing and critiquing arguments with each other.

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27.2 Teaching Context

We have used these techniques to promote discourse and appropriate argumentation in our classrooms. It is appropriate for students at all levels since the scaffolding provides support for students who need it, but its presence does not hinder those who no longer need it. Students may choose to use the scaffolds or not.

This activity is useful in any situation where argumentation, discourse, or critique of any kind is being utilized. While we have used it in science classes, the scaffolds could work in an inquiry setting in any discipline, but we find it most appropriate in maths and sciences where argumentation and critique are essential components of the professional skillset.

27.3 Overview of the Teaching Activity

When students are introduced to the idea of argumentation in the classroom setting—and later professional academic and workplace settings—they often bring their past experience of social arguments to the process. These experiences often carry negative feelings, and this can make students hesitate to engage in argumentation. Engaging in argumentation as a scientific practice is meant to be a constructive, fair, and reasonable activity. As many students do not innately bring these attitudes and skills to the process, we have found it important to purposefully provide this training. Explicitly teaching and modelling argumentation skills is the first step, but students also need additional support as they engage in argumentation themselves.

The scaffolds presented here are back-pocket question cards and sentence frames. Back-pocket questions are typically recognized as pre-formulated questions a person may choose to employ in a social or professional setting where "small talk" may be expected. You figuratively pull it out of your back pocket and use it as your go-to generic question when you need something to say. In the maths or science classroom context, we use pre-formulated questions and sentence frames that are printed on cards that can be physically handed to students as necessary. Alternatively, the sentence frames can be posted in the classroom for student reference as needed. Students can use these scaffolds as they engage in argumentation.

The activity begins with students who have crafted some type of evidence-based claim or explanation. The process of creating the claim or explanation could take many forms, and it could be a group or individual activity. Once the explanation is formulated, the students are logically moving toward argumentation as they question others' conclusions and discuss alternative findings. Argumentation is essential to sharpen their reasoning and can potentially lead to revisions in their own work. As the instructor facilitates and encourages argumentation, students will question and critique one another as they employ the presented scaffolds made available to them as sentence frames or question cards. Table 27.1 gives suggested sentence frames and back-pocket questions.

Table 27.1 Sample sentence frames and back-pocket questions

Sentence frames	Back-pocket questions
I disagree with you, because. . .	What makes you think. . .?
I see what you mean, but I also think. . .	Can you tell me more about. . .?
I agree with you, but I also notice. . .	What do you mean when you say. . .?
I agree with you, but I think you can add. . .	Why do you think that is important?
I agree with you, because. . .	What made you think that?
One thing I find interesting is. . .	Why did you choose to include this data?
If I understand you correctly, your point is that. . .	Is there anything you think you should have done differently?
This makes me think of. . .	What do you think would happen if. . .?
I am still confused about. . .	How did this help you with your explanation?
This idea makes me wonder about. . .	Can you think of any exceptions?

27.4 Runsheet and Lesson Plan

Prior to the lesson, the instructor should print or handwrite index-sized cards with the sentence frames on them. The instructor can also prepare the questions and sentence frames for display in the room (e.g., on a slide, a chart, or a poster). The question cards and a wall display can be used together. As a product of a prior inquiry activity, students will have explanations. This will be presented on whiteboards, chart paper, on a slide, as a poster, or as a written paper.

Instructor does…	**Students do…**	**Resources**
Ask students to prepare their explanation/claim for presentation. Prepare index cards for students.	Prepare the explanation/claim.	Suggested topics for the explanations and claims. Guidelines for preparation and presentation expectations.
		Before class.

Arrange students around the room in stations to present (1). Review any established norms for discussion or argumentation. Explain the rotation method, including time allowances for presentations, questions, and critique.	Move to their appropriate locations and set up stations as necessary.	Required presentation supports (e.g., whiteboards or chart paper) (2). 10 min
Distribute question cards (1-2 to each student) and/or point out the posted sentence frames (3). Set a timer and monitor the discussions. If students are struggling, hand them a new question card (4). Repeat this step until all groups/individuals have shared in each grouping.	Group/Student #1 shares a brief overview of their explanation/claim, the evidence supporting it, and their line of reasoning. After the presentation, the other students in the group use the sentence frames to probe, analyse, or offer suggestions and ideas.	Timer Question cards Sentence frames 10 min (round 1) plus 10-30 min for repeats
Debrief by asking questions and engaging the class in a group discussion (5).	Make encouraging comments about other presentations. Comment on how they intend to revise and improve their own explanation. Reflect on their argument and discourse practice	15 min
Total duration in-class = 40–60 min. Time depends on size of groups and length of presentations.		

Notes

(1) Arrange students in groups where 2–4 different explanations are present. If students are working in small groups to collaboratively craft a group explanation, pair up two groups to take turns presenting and critiquing. If students have prepared individual explanations, form groups of 3–4.

(2) Students could have their work written or typed on paper, or they could be using whiteboards or chart paper. If the format is written work, it can be helpful to prepare multiple copies and print them in advance for the students. We suggest the whiteboard or chart paper as a method that allows students to experience an activity similar to a poster presentation in a conference setting.

(3) Using the question cards ensures that students are "assigned" different questions to ask. This prevents the students from all asking the same questions and fosters a broader and more balanced discussion.

(4) If a group seems to be hesitant to engage in discourse, join them to facilitate by asking a question to start the conversation. It is strongly suggested that a timer be set to allow two minutes for presentation and eight minutes for follow-up questions and discussion, for a total of ten minutes per group. Groups should be notified when they have about one minute remaining in the discussion period.

(5) Some debrief ideas: Ask students to share a strength they noticed from one of the explanations they discussed. Ask students to share aspects of their explanation they will revise based on the critique received. If any groups had a unique line of conversation or a good example of discourse, you can ask them to repeat it. Students can also reflect on their own discourse and argumentation practice. To foster a safe environment and provide a positive experience for beginning argumentation exercises, we suggest the conversation be facilitated to include praise about peers while allowing students to point out areas for improvement for themselves.

27.5 Top Tips for New Instructors

1. Plan ahead and think about your students' personalities and abilities. Purposefully arrange the groups to positively accommodate all students. This may mean that you put students together who are more reserved, so they are not dominated out of the conversation. The goal is to give everyone the opportunity and support to engage in the argumentation, not simply make sure each group has someone talking and no dead air.
2. The goal with these scaffolds is to provide beginning argumentation experiences that are positive and confidence building. Because of this, the class discussion should focus on what students saw others doing well, and then how they are going to choose to self-improve. As a facilitator, promote good norms, and make sure no student feels bombarded with only statements about things they need to improve. The instructor can also ask students to repeat any good examples of points made during the small group discussions.

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The Power Opening: How to Grab Your Audience at the Start of Your Talk

28

Marlit Hayslett

Speaking - Engaging - Intent

28.1 Learning Outcomes

One of the biggest challenges we all face when sharing our research is how to engage our audience from the first moment. How can we persuade them that they should keep listening or reading? An effective response to this challenge is the power opening, also known as a strong start (Toogood, 2010). Power openings should be brief. Good power openings should capture your audience. Amazing power openings can be breathtaking.

After completing this exercise, the learner will be able to choose from several options of power openings and apply them to their oral presentations.

28.2 Teaching Context

I have been using power openings in my graduate research communication classes for several years now. This single addition has demonstrably improved the quality of the presentations. How? First, when done effectively, it creates an immediate connection with the audience. Second and consequently, it builds the speaker's confidence for the rest of the talk. When a speaker shares their energy with the audience, the result is a sense of belonging for everyone.

I introduce this activity by having the students work in groups. Each group member shares a brief description of their research. Then the other group members offer ideas for potential power openings. Once each student has a few ideas, they choose one and develop it fully for a class presentation. By working in groups first,

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each student gets more ideas than they could have come up with alone. Students at all levels and disciplines can benefit from developing this skill.

28.3 Overview of the Teaching Activity

The goal of this activity is to equip the learners with a few choices for opening their talks. The options are only limited by the student's imagination. In this lesson plan, I introduce five possibilities that science students tend to find easy to apply.

1. *A startling number, statistic or data point.* Depending on the context, it might be appropriate for the number to be large or small. For example, if talking about the conservation of a rare mammal, you could highlight how few are left. Or if writing about the volume of microplastics in the ocean, it is easy to find an enormous statistic that will trouble almost any audience.
2. *Call and response*: This is an easy technique for a beginner to try. The idea is to catch your audience's attention with a question. One student working on the implications of chemicals in drinking water held up a water bottle and asked "How many of you have drunk from one of these?" Of course, all hands go in the air. An added benefit of a *call and response* is that it can give the presenter valuable information about the audience. One important characteristic of a *call and response* is that it should have a finite set of responses, ideally two (e.g., yes or no). Why? Picture it: Imagine you start with "How is everyone doing today?" Do you really expect everyone to answer? If so, how? With open-ended questions, it is usually tricky for the audience to know how to respond. If you open by stating "Raise your hand if you eat meat," I know exactly how to respond. Although this method is often used at the beginning of a talk, more advanced speakers can weave this technique throughout their talk; this brings the audience back to attention at regular intervals.
3. *A vivid or provocative image*. In his final presentation a couple of years ago, one of my students used a black and white photograph of a lone woman trying to pull water from a well. He was a Ph.D. student in environmental engineering exploring new methods of water delivery in Africa. I still remember this image, which is a testament to the strength of his choice of a power opening.
4. *Spark curiosity*. For example, "If you met Yoda/Harry Potter/Marie Curie (insert appropriate celebrity name), what advice would they give you?" Or "Picture yourself in 2050. What is the energy source for your home?" This is a fun one, but can be more challenging to execute.
5. *Tell a personal story*. Of the techniques shared here, this is the one students are most reluctant to try—perhaps because stories evoke emotion and scientists may not want to be seen as emotional. Even still, I champion them as **the** power opener. The "story" I advocate students to play with is their personal story as it

relates to their research. Prompts to get them thinking might be "What excites you about your research?" "Why are you studying this?" "How did you get here?" The goal of the personal story is to create a connection with the audience. To see for yourself, try this with your students: Say "I want to tell you a story," pause for 5 seconds, and watch every eye in the room turn to you.

28.4 Runsheet and Lesson Plan

Power openings make the most impact if coupled with actual presentation assignments. In my research communication course, Ph.D. students offer a final presentation on their research. If the students do not have a specific presentation topic, see note (1).

Instructor does…	Students do…	Resources
Open the session with a power opening to model the lesson goal.	Observe	 >5 min
Present or show two examples of openings, one strong and one weak (2).	Critique each opening example with a rationale of what is effective and what is not. Students hear each other's rationales and explanations of what was effective for them (3).	Two TED talks (2) 10 min
Introduce the five power opening choices described above. Show examples.	Repeat critique as for the previous step (3).	 15 min
Visit groups to check in. Be prepared to assist with brainstorming. Often you can do this by asking questions: "What is the main idea you want to share?" "Are you able to do that with this choice of opening?	In groups of 3 or 4, share their research in 1-2 minutes each. After each person shares, the group brainstorms possible strong starts. For example, if a student is studying how inner-city gentrification is affecting minorities, options might be a story, a single statistic, or a powerful image.	 30 min
Out of class assignment	Develop a talk about their research (or a research article) that includes	

	a power opening. The talk can be delivered in an upcoming class session or submitted via video.	60-90 min
Extension If time allows in a future class session, ask each student to try two different strong start techniques and get the class to vote on which one is more effective. You could also do this in-person or as a video-based exercise (4).		5-7 min /student
Total duration in-class = 60 min + 60 min (i.e., 60 minutes for each session)		

Notes

(1) If the students do not have a specific presentation assignment, consider assigning the same topic to every student in the class (e.g., "You are giving a talk on the pros and cons of recycling. How would you start this talk?") The above lesson plan would be similar in terms of introducing the power opening options, but the brainstorming would then be individual rather than in groups. The exercise then becomes about the diverse approaches the students can develop to open the same presentation, and the different reactions each choice invites from the audience. In lieu of a broad topic, you could provide a few research journal articles to choose from.

(2) TED Talk speakers often leverage power openings. Find two that differ in their "power" for this discussion.

(3) Invite critique by the students. This is an important teachable moment because openings that some students find powerful will not resonate with others. I am surprised when I find an opening to be strong, and some students do not agree. I want to know why! Invite discussion about these differences. What was (not) appealing and why (not)? How much of this difference could be traced to the audience? It is valuable to highlight these contrasting receptions of the openings and then link them back to the importance of learning about the audience.

(4) To save class time but still facilitate learning, Student A prepares two videos with different strong starts. Student A's two videos are assigned to Student B for critique and feedback.

28.5 Top Tips for New Instructors

1. Power openings make the most impact if coupled with an actual presentation assignment. If done as a stand-alone activity without a topic focus, students struggle with how to make a choice or design the opening.
2. Prepare an example power opening of each of the above to demonstrate to your students. If you need ideas, watch a few TED Talks. These presentations tend to have reliably strong starts. Alternatively, if you can prepare a strong start for your

own research, it has potential to be even more meaningful by reminding your students of your passion and work.

3. It may be appropriate to mention your local context as students choose their power openings. Specifically, if your community is experiencing tension around an issue (e.g. water management, new pipeline, equity in schools, underrepresentation of community members), including it can be a powerful way to engage your audience.
4. While power openings are introduced here in the context of oral presentations, they are also effective in written formats.

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Physical Presence: How to Use Your Voice and Body to Be a More Dynamic Speaker

29

Marlit Hayslett

Speaking - Engaging - Listening

29.1 Learning Outcomes

In presentations, it is valuable to the audience to vary one's vocal quality, including volume, pace, pause-use, and filler words. It is also important to use appropriate body language, including stance, eye contact, and hand gestures.

By the end of this activity, students will have a better understanding and awareness of their physical and vocal presence in front of an audience. They will also have a better understanding of how to manage their presence, which leads them to consider how to improve it. An implicit goal of the exercise is to build the student's confidence in front of an audience, and their ability to reflect on "who" and "what" they present as a speaker.

29.2 Teaching Context

This group activity is intentionally playful with the goal of creating a low-stakes, fun environment for becoming more comfortable with one's own vocal identity and physical presence in front of an audience. For the content, I have used familiar children's poems and excerpts from movies. The assignment structure can easily be modified with other content (e.g., songs and speeches) so that the exercise can be repeated as often as class time permits.

Supplementary Information The online version contains supplementary material available at [https://doi.org/10.1007/978-3-030-91628-2_29].

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I have used this group activity in a class size of 25–30 students. Groups should be big enough so that an individual student does not feel uncomfortable or in the spotlight. I recommend groups of 6–8 students.

These activities are appropriate for students of any age in an in-person learning environment.

29.3 Overview of the Teaching Activity

These exercises are deliberately a bit frivolous and comical. I provide starter texts in the resources, but I encourage you to play with others. Be mindful of choosing passages that will resonate in your students' cultural context/s.

As a group, students read brief passages with specific instructions such as "read this as quickly/slowly as you can as a group." The passages can be from a variety of sources, but excerpts from children's rhyming poems and scenes from well-known movies tend to work well (1). By performing the exercise in a group, it takes the pressure off an individual and always results in laughter. This "low stakes" environment first introduces the area of focus but also invites repetitive practice.

A follow-on activity is to have the students perform individually. For this assignment, students can select from a collection of passages from movies and speeches, or they can suggest one of their own. If they choose their own, I ask them to send it to me for approval just to make sure it is the appropriate length and content. For this activity, the learning outcomes focus on vocal characteristics and body language. As such, the choice of passage is not of significant consequence as long as it inspires them to work on the skills and techniques.

29.4 Runsheet and Lesson Plan

Rather than using these as a one-time activity, I encourage you to think about how these exercises can contribute to students' skill-building across your available learning time period (workshop, semester, etc.). Because of the playful and informal nature of these exercises, it is easy to re-tool them with new content for additional practice. All slides in the Resources section are contained in Appendix 1.

Instructor does…	Students do…	Resources
Display sample passage on the screen and model the **Vocal Variation** exercise. Assign students to three groups of 6-8 or invite them to self-select groups.	Observe Acknowledge their group assignment and form groups	Vocal Variation Instructions (slides 1-2) 5 min
Invite first group of 6-8 students to the front of the room. Allow 1 minute to organize and discuss their approach (2). After the reading, facilitate brief discussion. "How did that feel? What did you observe?" (3)	Group confers about how to read the passage together according to the instructions (2). Group reads the passage, then participates in discussion.	Vocal Variation Passage 1 (slides 4-5) 7 min
Invite second group of 6-8 students to the front of the room. Allow 1 minute to organize and discuss their approach (2). After the reading, facilitate brief discussion. "How did that feel? What did you observe?" (3)	Group confers about how to read the passage together according to the instructions (2). Group reads the passage, then participates in discussion.	Vocal Variation Passage 2 (slides 6-7) 7 min
Invite third group of students to the front of the room. Allow 1 minute to organize and discuss their approach (2). After the reading, facilitate brief discussion. "How did that feel? What did you observe?" (3)	Group confers about how to read the passage together according to the instructions (2). Group reads the passage, then participates in discussion.	Vocal Variation Passage 3 7 min
Display sample passage on the screen and models the **Body Language** exercise	Observe	Body Language Instructions (slides 10-11) 5 min

Invite first group of 6-8 students to the front of the room. Allow 1 minute to organize and discuss their approach (2). After the reading, facilitate brief discussion. "How did that feel? What did you observe?" (3)	Group confers about how to read the passage together according to the instructions (2). Group reads the passage, then participates in discussion.	Body Language Passage 1 (slides 12-13) 7 min
Invite second group of 6-8 students to the front of the room. Allow 1 minute to organize and discuss their approach (2). After the reading, facilitate brief discussion. "How did that feel? What did you observe?" (3)	Group confers about how to read the passage together according to the instructions (2). Group reads the passage, then participates in discussion.	Body Language Passage 2 (slides 14-15) 7 min
Invite third group of 6-8 students to the front of the room. Allow 1 minute to organize and discuss their approach (2). After the reading, facilitate brief discussion. "How did that feel? What did you observe?" (3)	Group confers about how to read the passage together according to the instructions (2). Group reads the passage, then participates in discussion.	Body Language Passage 3 (slides 16-17) 7 min
Extension *Students:* In the next class, each student performs a passage of their choosing. *Instructor:* You can curate a set of acceptable passages for students to select or you can allow students free choice (4).		Passages for reading 5 min per student
Total duration in-class = 50 min		

Notes

(1) Ideas for passages include excerpts from speeches, movies, news articles, and even corporate responsibility statements.

(2) The students will be reading the passage in unison as a group. They should quickly decide how they will begin speaking together. For example, count down "3, 2, 1, start." They should read the passage all together on the screen as directed (e.g., read quietly without any pauses).

(3) The purpose of this debrief is to invite the students to think about what it would feel like to an audience if they spoke too quickly/too slow, mumbled/ articulated, etc. If the given prompt (i.e., "How did you feel? What did you observe?") is too vague, feel free to specify the question for the passage: *What would you think of*

your speaker if they never made eye contact with you? How would you experience the talk if the presenter was speaking quickly for 20 minutes? Your goal is to put them in their audience's shoes to emphasize why these arguably minor adjustments make a major difference. While the prompts may seem repetitive to you as an instructor, different groups of students are responding so it is valuable to present them with the inquiry as well.

(4) If you allow students to choose their own text, I recommend requiring your approval to ensure that the material is a good length (i.e., short) and is culturally appropriate and not offensive.

29.5 Top Tips for New Instructors

1. There are many resources available to aide in developing one's physical presence. This lesson plan is an elementary approach targeted at students who have no experience speaking in front of an audience.
2. Use a self-analysis tool that can help students discern which areas of their speaking they need to work on. I have developed the Vocal Profile Worksheet (Appendix 2) which is meant to build awareness of the user's vocal habits.
3. If your university has a drama department, make friends with a faculty member. Maybe they will do an occasional workshop for you or share some simple exercises with you to use in your classes.
4. As the students improve, you could make the exercise more complex by combining vocal variation with body language in the same passage. For example, they could read softly or loudly while not/making eye contact.
5. There are no shortage of online resources championing different techniques for building one's physical presence. Explore and have fun!

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Building Powerful Presentations Through Framing and a Call to Action

30

Amy J. Hawkins and Nicole C. Woitowich

Speaking - Organising - Distilling

30.1 Learning Outcomes

A critical component of effective communication is knowing who your audience is and honouring their role in the mutual exchange of ideas and knowledge. The paired exercises in this chapter encourage students to think about their research through various audience-specific lenses. Students will learn about the concept of framing in the context of delivering an oral presentation. They will also better understand how framing can affect the attitudes and behaviours of their audience when combined with a "call to action".

30.2 Teaching Context

To meet the growing need for broadly accessible science communication training, the American Society for Biochemistry and Molecular Biology created "The Art of Science Communication", an 8-week online course designed to help scientists communicate with non-expert audiences. These exercises are adapted from the course material and are applicable to students, scientists or STEM professionals at varying educational levels or career stages. These activities can be conducted either

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online or in-person; they work best when students have a predefined research topic to discuss.

30.3 Overview of the Teaching Activity

When working with an audience, one must always ask, “What connects the audience with the topic at hand? Why does it matter to them?” Framing is an important tool that helps an audience connect to a topic.

There are many types of “frames” which can be used to help the audience make sense of a topic. Frames also help to link a topic to societal or personal relevance. Types of frames might include “public accountability”, “social progress”, “morality”, “economic development” and even “uncertainty” or “conflict”.

A call to action (CTA) speaks directly to what a communicator would hope their audience would do with their newfound scientific knowledge. A CTA might encourage audience members to sign up for relevant clinical trials, support sustainable farming or contact their elected officials about a given policy. CTAs can also serve as a means to continue the conversation or encourage further learning and exploration. Notably, some of the very best CTAs create a narrative arc by calling back to the “frame” that speakers used to set up their presentation and connect with their audience.

This activity helps students view the concepts of framing and a CTA as distinct structural components of short talks or oral presentations, using a predefined scientific topic as an example. It also encourages students to put their audience’s needs, motivations or intentions first when communicating.

30.4 Runsheet and Lesson Plan

These “framing” and CTA activities can have two different starting points. In a graduate-level class, students may have already identified a research topic relevant to their coursework or an independent research project that they can bring to the class. For students without a current research project, an instructor may select and assign research topics in advance so students can do some background research to familiarize themselves with the relevant science content knowledge.

Instructor does…	**Students do…**	**Resources**
Describe the importance of knowing your audience and introduce the concept of framing (1).		Nisbet (2009) 15 min
Split class into groups of 3-4 (2). Monitor group conversations, serve as resource where needed.	Share their research topic (3) and intended audience (4) with their peers. Discuss 2-3 potential frames they could use with their audience (5). Provide peer-feedback to group members (6).	15 min
Invite one person from each group to share their audience, research topic, and chosen frames.	Representative group members share with the class.	15 min
Introduce the concept of CTAs (7). Monitor group conversations, serve as resource where needed.	Return to small groups and discuss potential CTAs which align with frames (8).	15 min
Invite one person from each group to share their audience, research topic, and chosen frames.	Representative group members share with the class.	10 min
Lead group reflection and/or discussion.	Participate in reflection and/or discussion (9, 10).	5 min
Extension Discuss post-class assignment (10).		5 min
Total duration in-class = 80 min		

Notes

(1) All communication is framed in some way. We define "framing" as an interpretive storyline that communicates how a given area of scientific research matters to the speaker's audience by finding a relevant tie-in that will connect with them on a personal level (Nisbet, 2009 has more details). Consider assigning students the Nisbet article as pre-class reading so they appreciate the variety of frames that can be applied to climate science or energy production. See the "Further Reading" section for additional resources regarding framing theory and a detailed case study of frames being used to describe a

Table 30.1 Example table produced in class

Research topic	Audience	Frame(s)	Call to action
Determining the crystal structure of a bacterial phytochrome photoreceptor	Non-expert adults	Technology/futurism: Did you ever think it would be possible to see inside the human body? This research helps us engineer the tools to do just that!	Learn more about how your tax dollars support science and advance medical technology
Developing a vaccine to alter the rumen microbiome in cattle	K-12 students	Humour: Younger audiences in particular may find methane emissions (farts and burps) from cows inherently funny	Support sustainable farming and individual dietary choices

retrospective study of proton-pump inhibitors prescribed to veterans with gastroesophageal reflux disease (Davis & Russ, 2015).

(2) These exercises take advantage of the social aspects of learning and work best in small groups of students who have a longitudinal relationship with each other.

(3) Research topics may vary by student population. For example, graduate students may prefer to use their own research projects or areas of scholarly focus. However, undergraduate students may benefit by using a topic assigned by the instructor which is relevant to their current course or program of study.

(4) Students are allowed to select any type of audience they would like for this exercise, although we encourage students to consider non-expert audiences as this helps them think creatively about multiple frames and CTAs which are perhaps outside of their comfort zone.
The term non-expert also encompasses science communication which occurs across scientific disciplines. For example, ornithologists and geologists are both scientists in their own right, but they are not likely to be experts in both fields (Kornei, 2021).

(5) Students or groups can create a table which outlines the research topic, audience, frame and CTA. Table 30.1 shows an example.

(6) Students should work together to identify if each student's proposed frames are applicable, relatable and realistic for an intended audience. Students may struggle with identifying (and avoiding) specialized, discipline-specific language in their explanations. They may also be unrealistic about what to expect from their audience's experience and/or educational backgrounds.

(7) The CTA at the end of a presentation is designed to give the audience a sense of satisfaction and leave them in an active position. This provides the audience with a sense of involvement, can foster mutual learning or understanding and can establish their further stake in what was discussed in the speaker's presentation.

(8) Throughout the process of sharing and giving feedback, students should try to both encourage and challenge each other, suggesting metaphors and relevant CTAs that their peers may not have considered.
(9) Students report that these activities help them engage in self-reflection and providing and receiving narrative feedback.
(10) Some instructors also explicitly build self-assessment and iterative design components into these exercises. For example, you can ask students to assemble the criteria they will use to judge an effective presentation and then use these to formatively assess each other's talks. After feedback, the students can re-format their presentation components and deliver their revised items later.

30.5 Top Tips for New Instructors

1. Instructors need not be experts in framing theory, but they should familiarize themselves with the concept.
2. These exercises have been successfully incorporated into online classes, undergraduate classes that focused on science content, and a two-day workshop for biomedical graduate students that focused on science communication.
3. Through completing the communication exercises, giving peer-to-peer feedback, receiving criticism and improving their initial presentation, students participate in metacognition. They engage in reflection and recognize their own conceptual change.
4. Another variation on this exercise would be to assign the same scientific topic (s) to individual students or small groups and to ask those groups to structure short talks using a variety of different frames.

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Website Links

For more information about the Art of Science Communication course, visit the American Society for Biochemistry and Molecular Biology website. (https://www.asbmb.org/career-resources/communication-course). *Accessed 20 Dec 2020*.

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Part VI

Practice Listening

Mirror Mirror: Learning to Listen to Your Audience

31

Julia Hathaway, Nicole Leavey, Peter Felsman, and Laura Lindenfeld

Listening - Engaging - Intent

31.1 Learning Outcomes

The exercise is called "mirror." The version described here includes an optional extension called "ball." After completing this exercise, the learner will understand how to communicate more effectively and empathically by following audience cues and making appropriate adjustments in the moment using body language and imagination. Through this experiential improvisation, the learner will learn to shift their focus from themselves to their audience.

31.2 Teaching Context

Science graduates and others who need to communicate complex information interact with diverse audiences in and out of the workplace. They may routinely communicate with interdisciplinary team members or others from outside their field (or subfield) and lay audiences, as well as friends and family. In some cases, they are called upon to speak with various publics who may have experiences,

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views, and biases that influence the way they receive information. If these communicators can keep the audience at the center of their message and connect with their values and interests, they will be better positioned to achieve their communication goals.

31.3 Overview of the Teaching Activity

In setting up this exercise, teachers describe how two rules of improvisation (“yes, and” and “make your partner look good”) are intrinsic to the exercise. Saying “yes, and” means accepting what your partner is offering you and developing the scene or—relative to communication—accepting the conversation or talk in a way that builds on their contributions. To “make your partner look good” entails behaving in ways that help them contribute to your co-creation. Both of these principles require that individuals embrace and build on their audience and communication context.

Mirror is a foundational improvisational exercise whose impact is apparent each time it is used. Working in pairs, typically the student leader initially fails to take their partner’s perspective into account. That is, they are having fun rather than considering whether or not their partner is able to follow. Similarly, in “ball,” the focus is on the creation of a particular imaginary ball and the nonverbal gestures necessary to toss it to their partner rather than helping their partner catch the ball. During the second part of “mirror,” there is usually a remarkable difference from students’ initial experience. The transformation students accomplish in a short time is profound.

31.4 Runsheet and Lesson Plan

This exercise is not physically difficult, but it can push students out of their comfort zone. Instructors should suggest that, as much as possible, students should be open to saying “yes, and” as this is where the most growth can occur. The other key is being a generous participant who wants to “make your partner look good.” The notes given for the instructor indicate how to lead and side coach the activity. The instructor may choose to demonstrate each activity with a willing partner before asking all students to begin.

Instructor does… (1)	**Students do…/Time**
*[PROMPT] "*Find a partner, stand opposite, and identify who will be Partner A and B. If it's physically necessary to sit, that's fine too."	Find partners and face each other at arm's length. Decide who is A and B. 1 min
*[PROMPT] "*Person A is the leader and B is the "mirror." It's B's goal to reflect the leader's every movement." *[SIDE COACHING] "*Follow your partner's cues." "Slow down."	Partner A engages in movement. Partner B follows or imitates the actions of the leader as closely and precisely as possible. 3 min
[PROMPT] Pause the group. Focus on and "unpause" a partner pair that is struggling a bit in order to engage in a demonstration.	The selected student partners continue the exercise while others watch. Students observe and offer input in response to the instructor's questions.
*[DISCUSSION] A*sk the group, "Can you identify who is the leader and who is the mirror? How? What is Partners A's goal?"	2 min
[PROMPT] Return to the exercise with the same Partner roles. Now, assign Partner A a specific goal: "Partner A, it is your responsibility to make sure B is following you. Your goal is to make it possible for them to mirror you closely. It is your responsibility that they follow you."	Partners resume exercise 2 min
*[PROMPT] "*Now, Partner B, you are the leader and Partner A, you are the mirror."	Partners switch roles and continue. 2 min
[PROMPT] Direct the student partners to periodically switch who is leading and following, giving each partner the experience of being responsible to their mirror. *[*PROMPT IF GOING TO BALL]* "Pause, and release your roles. Now..."	Partners continue mirroring each other, with leadership shifting back and forth in response to instructor cues. Again, the aim is to remain in sync with one another to the greatest possible extent. 2 min

*Resume here if including Ball [PROMPT] "*Now, in the same pairs, spread apart from one enough as if you will be playing a game of catch. Partner B, imagine you have a ball. What is its shape? What is its size and weight? Move it in your hands and then toss it to your partner. Play ball!"	Partner B creates an imaginary ball, establishes its properties, and passes it to their partner. The partners engage in a game of catch.	1 min
[PROMPT] "Now, change the ball before passing it, maybe from a tennis ball to a bowling ball." *[SIDE COACHING]* "Play with the ball to show its size, weight, and shape. Imagine that it represents something meaningful to your partner. What are you communicating to your partner? Is it an offer, or a demand? Should your partner be happy to receive it or anxious to be rid of it?"	Student partners toss the ball back and forth, shifting the size, weight, or nature of the ball and tossing it in accordance with those choices.	2 min
[PROMPT] Once students experience the many ways in which they can pass the ball, direct them to return to mirror. Ask whomever is holding the ball to be the leader.	Students return to the mirror exercise.	1 min
** if no ball extension, resume here [PROMPT] "*Continue/resume mirroring each other but now there is no clear leader or follower. You are both moving together in sync with no leader." *[SIDE COACHING]* "Someone observing should not be able to see a leader and mirror - you should be moving as one."	Students continue with the mirror exercise, moving together with no leader.	2 min
[PROMPT] Debrief the exercise using targeted questions (2).	Students offer thoughts and impressions of their experiences during the exercise(s).	5 min
Introduce the reflection assignment (3), posit how they may use it in future science communication contexts to reflect upon past communication or consider upcoming opportunities.	Students open up reflection assignment.	5 min
Total duration in-class = 24 min + 4 min extension activity = 28 minutes		

Notes

(1) While the origins of the mirror and ball improvisation exercises are uncertain, the mirror exercise is frequently attributed to the work of Viola Spolin and Neva Boyd. The ball exercise can be understood as an outgrowth of that work as well.

(2) Questions include: How was it to lead? Follow? What did you need to succeed in this exercise? How does this relate to science communication?
This exercise helps students understand that "following to lead" is the heart of audience-based science communication.

(3) After the exercise, students complete a reflection piece. Reflection is an important element of the Alda Method; when experiencing learning through improvisation, the completely experiential elements allow little time to reflect. Reflection enables each student to process the experience. Questions to ask might include: "What was that like/what did you experience?" "How did you adjust your physical movements when it was your responsibility to help the mirror follow you?" "What made it difficult to follow the other person? "What made it easy to communicate?" "How might this concept of 'leading is following' relate to communicating science?"

31.5 Top Tips for New Instructors

1. Mirror is a key component of the Alda Center science communication curriculum. In teaching science communication, listening is a very important element that is often overlooked. Helping students shift the focus from themselves toward their audience allows for the creation of a message that is specific to the communication context and built upon values that an audience finds meaningful. Connecting science with an audience and learning how to pivot based upon audience cues allow for more meaningful and engaging exchanges between speakers and audiences. This audience-focused approach builds common ground and enables authentic connection.
2. In side coaching this exercise, the instructor might advise students to think about being responsible. The aim is not about being complicated or clever. It's about being clear, specific, and responsible for your partner so that they stay with you. It is the leader's responsibility to perform movements that the mirroring partner can follow as closely and accurately as possible. The specific identification of the leader's goal as well as the partner pair demonstration for group observation is a particularly important key learning moment. In these experiences many can relate to the errors they were making and will consciously refocus their attention to their partner and, consequently, their audience. This link between the thoughtful consideration given to their partner and centering their communication on their audience should be made clearly in the exercise debrief. The two principles of improvisation—"yes, and" and "make your partner look good"—apply to every effective science communication.

Further Reading/Exercises

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32 See It, Speak It, Draw It, and Learn to Communicate in Simple Language

Holly Garrett Anthony and Kelly Moore

Listening - Speaking - Writing

32.1 Learning Outcomes

Communicating with specificity and clarity—orally and in writing—is essential in the sciences where accuracy and precision are paramount. Yet, many students have limited opportunities to develop these skills beyond the typical lab report, mathematical proof, or research essay. In these exercises, students will work in pairs/triples to see, speak, and draw/build maths and science constructs to hone their oral and written communication skills. This exercise helps students realize the importance and necessity of using concise, accurate, and descriptive detail to convey scientific ideas. It also helps them to develop their listening skills, deepen their ownership of discipline-specific vocabulary, and realize the consequences of vague non-descript communication.

Science graduates must be prepared for the oral and written communication demands that pervade the workplace, and these activities realistically simulate the nuances of communication in that environment.

32.2 Teaching Context

We have used these activities with both undergraduate and graduate secondary mathematics majors, and high school maths and physics teachers, to highlight the need for thoughtful and precise communication of mathematical concepts. These activities are easily adapted for use in all science disciplines and can be implemented as separate and distinct activities or collectively as one unit.

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Once these informal activities have been done, you can extend it to more formal graphs/representations from science. Science students are often engaged in undergraduate/graduate research opportunities and create posters/papers in which being able to clearly communicate about the data graphs, tables, etc. is essential. These activities develop their abilities to do this.

32.3 Overview of the Teaching Activity

We present two versions of the activity here. Instructors can use these as starting points to tailor the activity to their content and preferences.

32.3.1 Version 1: See It, Speak It, Draw It

Students sit in pairs (back to back). One person is Speaker; the other is Drawer. One student (Speaker) is given a visual representation (e.g. see Fig. 32.1) from math/science and asked to communicate how to replicate the figure to their partner (Drawer).

In *Round 1*, Speaker is tasked with describing the sketch with sufficient detail such that Drawer can replicate the sketch in its entirety (and accurately to scale) on their paper. Speaker should use appropriate academic vocabulary to describe shape, magnitude, orientation, coordinates, etc. as needed so that Drawer can accurately draw the figure described.

In this round, Drawer is not permitted to speak except to indicate when they are ready for additional information, and they may not ask any questions or restate what they think Speaker has said. When Speaker determines that they have provided all of the detail necessary for Drawer, and Drawer indicates that they are finished, Round 1 concludes, and they may now compare the sketches. They should discuss discrepancies and inaccuracies in the sketches and how those details could have been communicated more clearly by Speaker and/or how they were misunderstood by Drawer.

The students then switch roles, and the instructor provides a new sketch/figure (see Fig. 32.2 for science example). The process is repeated.

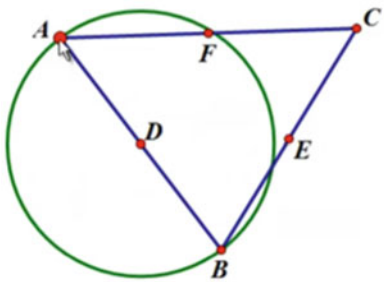

Fig. 32.1 Geometric sketch (visual representation from mathematics)

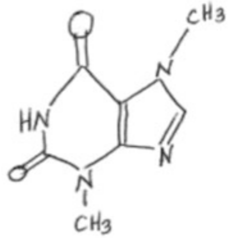

Fig. 32.2 Molecule structure sketch (visual representation from science)

Round 2 is the same as Round 1 except this time Drawer can ask yes/no questions for clarification. *Round 3* is the same as Rounds 1 and 2 except Drawer may now ask clarification questions of any type as needed throughout the process. This round is more conversational.

32.3.2 Version 2: See It, Write It, Build It

In this version, students are assigned to pairs. One person is Writer; the other is Builder. Writer and Builder begin in separate rooms—or in the same room with a partition to prevent Builder from seeing the original structure. Writer is presented with a model or figure—built from LEGO® bricks, blocks, and/or craft materials (Styrofoam, chenille stems, paper clips, etc.)—and they are given a predetermined timeframe (10–15 min) to write a thorough description of what they see with sufficient detail such that Builder can replicate the model in its entirety (and accurately). Writer may *not* draw pictures/illustrations. Builder is provided with an array of materials that may (or may not) be needed to build the figure.

At the end of the timeframe, Writer delivers the written description to Builder who is tasked with following the written specifications to recreate the model. Builder and Writer are not permitted to talk during the build. When Builder determines that they are finished, Writer can reveal the original model—either by removing the partition or by walking together to the other room—and they should compare any discrepancies and inaccuracies in the models and discuss how those details could have been communicated more clearly by Writer and/or how they were misunderstood by Builder. The students now switch roles, and the Instructor provides a new model. This ensures that everyone has the opportunity to be both a Writer and a Builder. Note: if facilities permit, this activity can be expedited by having both partners observe (different) models at the same time, then switch descriptions (without seeing the other's model), and both build at the same time.

32.4 Runsheet and Lesson Plan

Details for *Version 1: See It, Speak It, Draw It* and for *Version 2: See It, Write It, Build It* are provided.

Instructor and Students do…	**Resources**
Version 1: See it, Speak it, Draw it	
Round 1: *Instructor:* Put students into pairs (Speaker & Drawer) and ask them to sit back-to-back. Provide Speaker with a representation from maths/science (1) and provide Drawer with pencil/paper. *Students:* Sit back-to-back. After the activity is explained, begin explaining and drawing.	Images of maths or science figures (1) 5 min
Instructor: Move about the room monitoring the pairs to ensure that only Speaker is speaking. Listen to students' use of vocabulary and detail (or lack thereof). Consider what you will share from your observations in the whole-class discussion. *Students:* Speaker describes in as much detail as possible the figure they were given. Drawer tries to recreate the figure based only on the words provided by Speaker. (2)	Paper and coloured pens (e.g., felt-tip markers) 12 min
Instructor: Call "Time" (3) and ask pairs to compare the given figure with the one sketched by Drawer. *Students:* Discuss discrepancies and inaccuracies in the sketches and how those details could have been communicated more clearly by Speaker and/or how they were misunderstood by Drawer.	10 min
Instructor: Ask students to switch roles. Provide new sketch to Speaker. *Students:* Repeat previous steps in Runsheet with Speaker and Drawer switched.	New image 20 min
Round 2: Repeat Round 1 steps, but allow Drawer to ask yes/no questions for clarification. Make sure both students have the opportunity to be Speaker and Drawer (4).	New images 25 min

Round 3: Repeat Round 1 steps, but allow Drawer to ask any clarification questions they wish. Make sure both students have the opportunity to be Speaker and Drawer.	New images 25 min
Instructor: Lead whole class discussion to highlight the importance of details, accuracy, appropriate vocabulary, etc. when conveying scientific ideas. Generalize the learning to professional science presentations, posters, and publications (5). *Students:* Participate in discussion.	15 min
Version 2: See it, Write it, Build it (6)	
Before class: Build figures (7) using bricks, blocks, or other materials and plan a location for it so that you can manage when students see which models.	Built Model TBD
Instructor: Put students into pairs. Make the model available for Writer to view (8). Provide Builder with an array of materials they may need (9). *Students:* Writer describes the model they were shown (without using diagrams/pictures) (10). Builder tries to recreate the figure based on the instructions provided by Writer.	Materials to replicate the build 15 min
Instructor: Announce "Time" and ask pairs to compare the rebuild with the original build. *Students:* Discuss discrepancies and inaccuracies in the builds and how those details could have been communicated more clearly by Writer and/or how they were misunderstood by Builder.	10 min
Instructor: Ask students to switch roles. Provide model to new Writer. Students: Repeat process with student roles reversed	25 min
Instructor: Lead whole class discussion to highlight the importance of details, accuracy, appropriate vocabulary, etc. when conveying scientific ideas. Generalize the learning to professional science presentations, posters, and publications (5).	15 min

Students: Participate in discussion.	
Extension Put students in teams of three: Speaker, Writer, and Builder. Provide a built figure for Speaker to observe. Speaker observes the pre-built model and describes it orally to Writer who tries to draw/write what has been described without viewing the model. This is then passed along to a Builder who uses the information provided by Writer to recreate the original model.	Built model and materials to replicate the build. 30 min
Version 1: Total duration in-class = 25 min (per Round) **Version 2: Total duration in-class** = 45 min + 30 min for extension activity	

Notes

(1) The provided figure from maths/science can be in the coordinate plane, or not; and with or without measurements. You can choose to provide measurement tools (rulers, compasses, protractors, etc.) to both students if you wish.
(2) Drawer is not permitted to talk except to ask Speaker to wait or continue.
(3) We recommend 10–15 minutes for the early rounds. Students will get faster as they progress through the activities.
(4) Depending on your time constraints, you could choose to omit Round 2 and move on to Round 3 or vice versa.
(5) You can choose to lead whole-class discussions between rounds and/or wait until the end of class. Students typically discover (after messing up their early attempts) that they need to start by communicating an overall "big picture" of the sketch (e.g. "this picture is about gravity"); then move on to describing the larger features of the sketch (e.g. "start with a large rectangle that runs about 1 cm from the edge of the page all around. Inside this is a circle of about 10 cm diameter that intersects with the top of the rectangle".); and then to the finer details (e.g. "the vertices of the rectangle are labelled A through D clockwise beginning with A at the upper right vertex".).
(6) More ideas for how to run this version can be gleaned from the Science Olympiad "Write It Do It" events (see Website Links).
(7) We think there is value in using instructor-built models so that it prompts the use of specific vocabulary terms (e.g. anatomical descriptions—medial, lateral, etc.). Models can be abstract or concrete (e.g. truss bridge).

(8) If space permits, it is ideal to have the models viewed by Writers in a separate room and/or behind a partition so that Builders cannot see the model.
(9) We have found it useful to provide Builder with additional materials that are not needed for the build. Often Writer has assumed Builder will only have the same materials as were used in the original figure, and their detail is insufficient for Builder to be successful. For example, provide different colours and lengths of chenille stems (even if only 1 colour of 1 length is needed).
(10) An example of how to do this using only words might be: "I saw a red rectangle with one pair of opposite parallel sides about 7 cm in length and the other pair of opposite parallel sides were about 4 cm in length".

32.5 Top Tips for New Instructors

1. Some students may struggle to get started with the activity. One idea is for the instructor to "act out" an example with a fellow academic. Together they can complete Speaker/Drawer activity in front of the class to help clarify the activity and help indicate to students *how* to describe the images.
2. Don't let students choose their own images at the beginning of this exercise; they tend to choose things that don't lend themselves to the exercise (e.g. a picture of a tiger or a face).
3. While presented here as two versions to be conducted in sequence, these could be thought of as four or five (including the extension) separate activities that could be interwoven across a course at different points in time as a way to revisit these ideas. It is not necessary to complete all of these rounds and versions in one or two class meetings.
4. Some student teams will work more quickly than others for *Say It, Speak It*. We recommend having several copies of several different figures (perhaps increasing in complexity) so that pairs who finish early can be given more complex figures to work with while they wait on their peers.
5. Sources for figures/models are endless. For more basic images, you can source them from textbooks and websites or create them by hand yourself. Academic journals are useful for more complex figures and/or graphs.

Website Link

Science Olympiad "Write It Do it". (https://scioly.org/wiki/index.php/Write_It_Do_It). *Accessed 21 Jan 2021.*

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Understanding the Hidden Meanings of Words Using the Word-Association Game

33

Jessica Fletcher

Listening - Speaking - Engaging

33.1 Learning Outcomes

Scientists are often described as having the 'curse of knowledge', a cognitive bias in which the communicator unintentionally assumes the audience has sufficient background knowledge to permit understanding. Students struggle to 'forget' years of science education and training in order to put themselves in the shoes of their audience to understand how to effectively adapt their communication practices in a clear and compelling way. This activity encourages students to go beyond a consideration of language limited solely to technical difficulty (identification of jargon).

By the end of this activity, students will be more aware of the associations and connotations words can have in relation to everyday colloquial meaning and emotional context and how this can influence communication and response by an audience.

33.2 Teaching Context

I have used this activity to help second year undergraduate medical science students reflect on their communication practices. It is useful for students who are beginning, or expanding on, their exploration on communication with non-specialist audiences. It stimulates students to discuss how subconscious 'knee-jerk' responses to certain words can cause confusion in an audience, or possibly evoke a strong emotional response, that could derail meaningful engagement.

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This activity is also useful for the instructor to explore students' understanding and conceptions around particular words in the curriculum to allow for clarification of misunderstandings of common terminology.

This activity is suitable for middle undergraduate to graduate classes and can be applied in any science discipline. It can be delivered in 1 h or in a longer 1.5–2 h session using the optional extension activity. It can be adapted for varying course sizes in both online and in-person formats.

33.3 Overview of the Teaching Activity

The first part of this activity requires students to consider a list of words provided by the instructor and discuss both their scientific meaning and how a non-specialist audience may interpret the words within their everyday context. In a word association game, one participant says a word, and the listener responds with the first word (s) that comes to mind. This may be perceived as simplistic, but the listener's response can reveal a lot about how they associate, and therefore understand, the word. For example, a relatively simple word such as 'medium' means 'a substance in which an organism is grown' in a scientific context, but in a colloquial context this may refer to clothes sizing or an individual who can communicate with the spirit world. Students are asked to discuss how they think this could lead to misunderstanding by the audience and how they could clarify their communication.

Students are then asked to read the list of words again and consider whether they may have inherent emotional connotations. For example, mutation is a key experimental technique in many fields of science and research and in nature can have both positive effects (evolution) and negative effects (disease). Yet the word 'mutation' holds decidedly negative emotional connotations to a non-scientist audience (due to associations with cancer and disease). Students are asked to discuss how they think this could impair an audience from meaningfully engaging with the scientific topic.

Each student is then required to present a one-minute talk on a science topic of their choice or one set by the instructor. Other students in the group listen and identify any words that may be interpreted differently by a non-specialist audience.

33.4 Runsheet and Lesson Plan

Prior to class, students are asked to prepare a one-minute talk on a scientific topic of their choice, or one assigned by the instructor, aimed at a non-specialist audience. The following runsheet for the workshop is timed for groups of five students. Timing can be adjusted for differently sized groups.

Instructor does…	**Students do…**	**Resources**
Provide a list of five to ten discipline-specific words and ask students to consider their scientific and colloquial meaning (1).	Read the list of words and consider the scientific and colloquial meaning of each word. Discuss how differences could impair clarity of communication (2). *Optional:* Each student can assume a different 'audience' viewpoint (3).	List of words (4) 15 min
Ask students to review the same list and identify any emotional connotations (5).	Read the list of words and consider the emotional connotations of each word. Discuss how this may influence meaningful communication (6). *Optional:* Each student can assume a different 'audience' viewpoint.	List of words 15 min
Facilitate group presentations and discussion.	In groups of five, each student delivers their prepared 1-minute presentation. Other group members make note of any words that have colloquial meaning or emotional connotations. Students discuss identified words and decide if/how communication can be adapted (7).	30 min

Instructor does…	Students do…	Resources
Extension - Provide a soundbite or news video and ask the students to identify words that may have different colloquial meaning or emotional connotations (8). The students work in groups to identify the words and discuss how they may influence communication (9).		Media clips (10) 30-60 min
Extension – Another extension option is to ask students to think about the kind of language that may have a dual meaning in a work environment (12). Ambiguous or emotive language does not necessarily have to be scientific. Ask students if they can think of examples of language that should be used with care in the workplace (e.g., gendered language, diminutives, and even apparently humorous language can be emotive for people). You can also ask students to write a script for introducing a speaker, or chairing a meeting, and then critique it for gendered, or dismissive language, or the capacity to be emotive (in both positive and negative ways). Asking students to revise this script so it is less likely to trigger negative audience reactions can be a great professional development exercise.		30-60 min
Total duration in-class = 60 min for main activity + 30-120mins for extension activity depending on class size and the number of examples chosen.		

Notes

(1) Avoid 'jargon' or overly technical words. Appropriate words are those commonly used in a scientific context but are simple in their nature (e.g. culture, affinity, organic) and have different meanings in a colloquial context. See Table 33.X and Further Reading for examples.

(2) Depending on class size, this can either be done with the entire class or in groups.

(3) Ask each listener to adopt a different audience persona (e.g. a schoolchild, a politician, a teenager) to consider how word association may vary by audience background.

(4) For smaller classes, project these onto a screen one word at a time. For larger classes, print onto individual cards to provide to groups.
(5) You may wish to provide a new list of words for this activity to broaden the students' consideration of different words.
(6) Occasionally, the activity words may evoke strong emotions for some students based on their own personal life experiences. Instructors should take care not to invalidate or dismiss student responses during discussion.
(7) In certain contexts, evoking an emotional response in an audience could help to promote meaningful engagement. If the emotional association is positive, and understanding is not impaired, students may find that they do not wish to adapt their language. When considering words that have different colloquial meanings, it may not be necessary to replace the word, but rather facilitate communication by adding an additional explanation. In some cases, students could even use it as a humorous element to point out the different meanings of a word.
(8) Depending on available time, students could be instructed to locate and analyse a media clip of their own choosing, and the follow-up workshop time can then be used as an opportunity for them to present their thoughts.
(9) If completing this activity in groups, each group can be assigned a different media clip and present their thoughts back to the rest of the class. Media clips from different sources on the same subject can help students appreciate the approaches taken by different media outlets.
(10) Short clips (1–2 min at most) work best, and time should be allocated for the clip to be played two or three times during the exercise.
(11) Relating this exercise to potential work environments is valuable. If a graduate is working in a highly technical science environment, they will have more freedom to use very technical language. If they are working in a more mixed-discipline environment, they will likely need to consider how others in their environment are perceiving their language.

Whatever position or work environment they find themselves in, it will be important for them to consider the (un)intended effects of their word choice (e.g. calling women 'girls' is often offensive; describing your professional role as 'parenting' can be demeaning or triggering for others, and it is better to describe your role as one of 'leadership' or 'mentoring'). Many students will already be working in science and non-science positions (e.g. in the service industry). They will probably be able to share their first-hand experience of words that have been used in their workplaces and which they found confusing or triggering.

33.5 Top Tips for New Instructors

1. This activity works best using discipline-specific words that students have encountered in their studies. The activity is recommended for middle undergraduate classes and upwards as these cohorts should have been introduced to

sufficient terminology for completion of this activity. If you are finding it hard to think of words, a good place to start is the glossary of any key undergraduate textbook used in your subject area.

2. Initially, it may be difficult for students to adopt the 'non-specialist' viewpoint. This can be facilitated by mixing students (if the class is comprised of different programmes of study) and providing examples, or it can be fun to invite a colleague from a different discipline to demonstrate the activity for the students.
3. Once students get into the flow of the activity, they are often surprised at how different their thought processes and word associations are from non-specialists. This can help stimulate them to consider word choice more carefully when communicating to non-specialists (as is the intention of the activity) and can be encouraging for them to see how far they have come in their learning journey and the knowledge that they have acquired.
4. The work-word association extension exercise takes this activity from training in 'communication with lay audiences' to a 'communication in the workplace' professional development opportunity. This is particularly valuable for students who are going to a work placement or likely to be seeking work.

Table 33.X: Example words with different science and lay meanings and associations

	Scientist	**Non-specialist audience**
Affinity	The tendency of a chemical species to react with another species to form a chemical compound.	A natural attraction or connection to a person, thing, idea.
Alien	A non-native species that has been introduced to an area outside of its normal distribution.	An extra-terrestrial, or a person who is not a national or citizen of a country. There may be inherent negative connotations.
Basic	A substance with a pH greater than 7.	Uncomplicated or straightforward. In pop culture slang, this term is used as a derogatory word for someone who is considered to be unoriginal.
Blind	Used to describe a study in which participants do not know which study group they are in (e. g. either taking an experiment drug or a placebo).	Loss of sight or to describe an individual lacking awareness or an unwillingness to understand.

	Scientist	Non-specialist audience
Calculus	A solid mass (stone) found in the body, e.g. a kidney stone.	A branch of mathematics.
Cell	The basic biological unit of all living organisms.	A place where criminals are locked up! Another name for mobile phone.
Culture	To grow bacteria or cells in a laboratory environment.	The characteristics, ideas, and social customs of a group of people.
Depressant	A drug to reduce neural stimulation.	Something that makes you feel depressed.
Gall	An abnormal swelling of plant tissue.	A personal characteristic of boldness.
Insult	A term used in medicine to describe an event which causes physical or mental damage.	A verbal attack of disrespectful or hurtful remarks.
Organic	A compound that contains carbon or matter that has come from a once-living organism.	Food that has been produced by certified farming standards, e.g. relating to pest control practices. It may have positive emotional connotations as people relate it to being 'healthier' or more environmentally friendly.
Radical	An atom or molecule with at least one unpaired electron.	An individual who takes extreme action to influence politics or social change. There may be inherent negative connotations.
Solution	A mixture of a liquid (solvent) in which one or more substances (solute) have been dissolved.	The answer to a problem.
Stress	The force acting on a unit area of material.	The feeling of being pressured, overwhelmed, or unable to cope. May have inherent negative connotations.
Volatile	A substance that easily evaporates at normal temperatures.	Unpredictable. Liable to rapidly lose one's temper and become violent. May have inherent negative connotations.

Further Reading

Smith, A. N. B., & Merkle, B. G. (2020). Meaning-making in science communication: A case for precision in word choice. *Bulletin of the Ecological Society of America, 102*(1), 1–6. https://doi.org/10.1002/bes2.1794

Website Link

The Word Association Game: Activity Examples. (https://cronfa.swan.ac.uk/Record/cronfa56548). *Accessed 29 Mar 2021*.

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34 Learning to Be Part of the Conversation Through Blogging and Blog Commenting

Matthew Wood

Listening - Conversation - Writing

34.1 Learning Outcomes

This activity focuses on developing an awareness of how opinions and understandings can be influenced through informal discussions around science topics, wherever they might occur, and the potential benefits and concerns of including a variety of perspectives and participants. Students will identify how their own thoughts and opinions can be shaped by comments on a blog article and begin to understand the potential for their own comments to influence others. They will consider the potential role that all members of a discussion can play and the value of listening to other's perspectives.

34.2 Teaching Context

It is not uncommon for science communication to be imagined as a top-down, one-way dissemination of information and expert analysis to the public. Although this type of communication constitutes an important segment of science communication practice, it is also important to acknowledge that a wide variety of players, many of whom would not be considered scientific experts, are involved in public discussions around science. This includes informal, online discussions which can have important impacts on public understanding of and attitudes toward science.

I use this activity to broaden students' awareness of the range of potentially important settings in which science is discussed and communicated and the influential role of non-expert participants. It can be used as part of a broader strategy to

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develop students' understanding of the complexity of public discourse on science or as a stand-alone exercise to encourage student appreciation of diverse inputs into science-related discussions. It is suitable for science students at any level of undergraduate or graduate program.

34.3 Overview of the Teaching Activity

Students are directed to a science blog article that has been set up in a private or semi-private online space for the purpose of the class. After reading the article, they compose and post a comment expressing their own thoughts or opinions. They then read other students' comments and respond to those they are interested in or take issue with. In this way multiple discussions build up focusing on a range of viewpoints and related issues around the blog article topic. This multifaceted discussion becomes the basis for a reflection exercise.

In a guided discussion at the conclusion of the activity, students first reflect on their own actions and experience (e.g., how they felt contributing to a public discussion, their objectives and motivations when commenting, how to present ideas clearly). Next, they reflect on how their understanding and perspective of the topic were influenced by the online discussion (e.g., clarification or change in understanding, new viewpoints or realizations, reinforced or challenged opinions). Finally, students consider where such discussions occur in the realm of public discourse on science and how they could be influencing public understanding and attitudes towards science.

34.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Optional: Lead a brief discussion on science blogs, and their utility for science communication. (1)	Voice opinions on the value of blogs.	 5 min
Point out the potential for discussion to develop in a blog's comments section. Raise the question of the value of comments. Explain the activity. (2) Give brief pointers on commenting and online etiquette. (3)	Voice opinions on why comments are valuable.	 5 min

Start the activity; monitor online activity and assist students if required. Contribute to comments if necessary. (4)	Read blog article and comment with own ideas/ opinion. Read and respond to other comments.	Blog article in private online space (5) Student access to internet (6) 45-50 min
Halt the activity. Guide a reflective debrief where students discuss how they are influenced by their involvement in commenting. (7)	Reflect on and discuss influence of commenting.	15 min
Total duration in-class = minimum 75 min. Can be extended for longer. Allow enough time for the reflection task, which could be moved to written homework or online discussion board if necessary.		

Notes

(1) My courses include a prior class which addresses the merits and challenges of blogs as a tool for science communication, so students have already considered the communication value of science blogs when they begin this activity. If the activity is run in isolation, students benefit from a short primer on science blogs and their value for communicating science, to contextualize the activity.

(2) Students read the blog article; post a comment expressing their own thoughts, opinions, or questions; and then respond to other comments. I set a minimum target of one comment and three replies for each student. For a class of 30 students, this approach yields 120 contributions and a discussion which is rich enough for productive reflection. At this stage you do not need to warn students that they will be asked to reflect on the activity.

(3) I find it useful to provide some basic tips on appropriate writing style for comments, along with general online etiquette. Some links to resources on these topics are provided in the Website Links section. Spend more time on this if you wish to take a stronger focus on communication skills.

(4) You may wish to add a comment or two of your own. This might be to model the commenting style you expect or to inject a little more diversity into the discussion if it is needed. However, to maintain students' sense of ownership of the discussion, you should minimize your visible presence in the comments section. Keep your comments to a minimum, and post anonymously.

(5) Prior to the class, set up a short science blog article online specifically for the purpose of the activity. Choose a topic that is relevant to your discipline, likely to be interesting and easily understandable for your students, and an area on which all students should be able to offer some kind of opinion. Topics broadly relevant to students' everyday lives tend to work well (e.g., lifestyle, food, health). The article should preferably be written in a style aimed at a broad general audience.

The blog article can be hosted on a free blogging site. Set the blog to be private or excluded from search engines. You can then share the link with students with little risk of anyone else finding the site. Alternatively you might use your institution's learning management system or virtual learning environment. It is important that your choice of platform has threaded comments to maintain the structure of the discussions that emerge. Creating your own online space for the activity rather than using a "live" blog helps students feel more secure and comfortable expressing their ideas, and the blog article and comments can be deleted after the activity.

(6) This activity assumes internet access for all students, but prepare a small number of printouts of the blog article for students without their own device. The instructor or another willing student can submit comments on their behalf.

(7) The reflective discussion can be completed as a whole class or in smaller groups. It is important for students to hear each other's observations, so small group discussions should ideally include reporting back to the whole class.

For the discussion, ask students how they felt about contributing their ideas to the comments section and what their commenting motivations and objectives were. Then ask students to consider how reading the comments influenced their own understanding, ideas, opinions, and perspectives. Invite students to consider how their comments might have contributed to the changes discussed by other students. Finally, discuss where in the public sphere these types of discussions on science and related topics are happening, who might be involved in them (participants and observers), and what influence they might have on public attitudes toward science topics.

34.5 Top Tips for New Instructors

1. I find that students participate very actively in this activity. They seem to find it novel and exciting to comment on a blog. They also enjoy the freedom of submitting comments to an online platform rather than speaking directly in front of their peers. It is important not to restrict students unduly during the commenting stage. Allow frivolous comments if they appear, and let the discussion develop organically.
2. You can extend the time allowed, but I have found that too much time dilutes the activity and impact of the reflection. I have run this activity entirely online over a one-week period, but I find the more intensive commenting format is more effective. The reflection, on the other hand, should not be rushed. Students need time to recall their experience, take a metacognitive perspective, and develop their own realizations.
3. The learning in this activity happens in the reflective discussion, and as far as possible this should be derived from the students' own observations and analysis. This activity is about encouraging students to broaden their perspectives rather than dictating what they should think. Allow students to develop their own opinions and conclusions. As an instructor you will want to guide students to

particular observations that you feel are important. A certain amount of nudging is fine, but all opinions should be heard, and if they are disputed students should have an opportunity to justify and defend.

Further Reading/Exercises

There have been many studies investigating the influence of public discussions (including comments sections) on attitudes. The following are a few examples.

Anderson, A. A., Brossard, D., Scheufele, D., Xenos, M., & Ladwig, P. J. (2014). The “nasty effect”: Online incivility and risk perceptions of emerging technologies. *Journal of Computer-Mediated Communication, 19*, 373–387.

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Winter, S., Brückner, C., & Krämer, N. C. (2015). They came, they liked, they commented: Social influence on Facebook news channels. *Cyberpsychology, Behavior and Social Networking, 18*(8), 431–436.

Website Links

Free options for blog space.

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University of Waterloo Centre for Teaching Excellence: Online discussions. Tips for students. https://uwaterloo.ca/centre-for-teaching-excellence/teaching-resources/teaching-tips/developing-assignments/blended-learning/online-discussions-tips-students. *Accessed 29 Jan 2021*.

Considerations for online etiquette. Achieve Virtual Education Academy: 7 rules for online etiquette. https://achievevirtual.org/7-rules-for-online-etiquette/. *Accessed 29 Jan 2021*.

An introduction to reflective thinking—what it is and why it is useful: University of Hull: Reflective writing. Introduction. https://libguides.hull.ac.uk/reflectivewriting/reflection1a. *Accessed 29 Jan 2021*.

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Part VII

Practice Investigating

35 Using a KLEWS Chart to Collect and Organize Information During Investigations

Kelly Moore and Holly Garrett Anthony

Investigating - Organising - Arguing

35.1 Learning Outcomes

Making evidence-based claims and explanations is an important practice in science. The formulation and revision of scientific explanations regularly involves practices such as planning and conducting investigations, technical reading, and engaging in argumentation (Zembal-Saul et al., 2013). Students often have difficulty formulating reasonable explanations, yet this process is foundational to communication in science. This exercise provides students with scaffolding to support them throughout the process of developing an evidence-based claim and explanation. The exercise is important for students engaging in scientific inquiry who are expected to present a concluding statement either in written or spoken form. After completing this exercise, students will be able to articulate a claim, support it with evidence, and include science-supported reasoning to illuminate how the claim and evidence connect to create a full scientific explanation.

35.2 Teaching Context

We have used this activity to help guide students through scientific investigations, from introductory activities to final presentations. It is most useful for students in introductory science courses, and it has been modified from an activity originally purposed for younger students. However, we have found that students at the

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collegiate level can benefit from scaffolding to support their critical thinking towards the development of scientific claims, particularly if they do not have a strong background in science research activities. Especially in settings where students may be completing an extended inquiry activity, this scaffolding gives students a consistent baseline for organizing their thinking as they identify what they know about a given topic, what they want to know, whether their questions are researchable or testable, and how their understanding relates to accepted principles and ideas in science.

This activity can be integrated into any current laboratory investigation or inquiry activity with little extra time added. It is most beneficial for a longer laboratory setting or an ongoing long-term investigation.

35.3 Overview of the Teaching Activity

Students use a KLEWS chart to organize their thinking throughout the inquiry process (Hershberger & Zembal-Saul, 2015). A KLEWS chart begins with a widely used KWL graphic organizer chart that organizes what students already know (K), what they wonder or want to know (W), and what they learn (L). KWL charts are appropriate across many disciplines and age levels, but the KLEWS chart becomes specific to science with the added E and S columns (see Fig. 35.1). Students will be recording evidence (E) and identifying related science concepts (S) in the graphic organizer over the course of the laboratory experience.

By continually organizing thinking, prior learning, observations, and ideas throughout the inquiry, students will have the tools needed to craft their scientific explanation using another scaffolding method known as a Claim-Evidence-Reasoning (CER) framework. A CER is a scaffold to incorporate scientific explanation into the classroom (McNeill & Krajcik, 2012).

Guiding Question/Topic: ______________________________

K (what I **K**now)	L (what I am **L**earning)	E (**E**vidence & observations)	W (what I **W**ant to know**)**	S (**S**cience concepts)

Fig. 35.1 Sample KLEWS Chart

35.4 Runsheet and Lesson Plan

KLEWS can be applied to any lesson and is most beneficial when a guiding question is given to the students.

Instructor does...	Students do.../Time/Resources
Introduce the KLEWS chart and ask students to consider the guiding question/topic. Ask students to complete the K column with that they already know about the guiding question/topic.(1)	Students individually brainstorm what they know, from life experiences or previous learning, about the guiding question/topic. Students record this in the K column. Large KLEWS chart on chart paper or written on a classroom board. Individual student KLEWS charts for their work and notes. 10 min
Ask students to share what they have included in their K column and facilitate a class discussion. When students use science vocabulary or concepts, list those in the S column. If students bring up ideas that are misconceptions or lack some understanding, elaborate by asking questions. You may list these in the W column, as students "want" to gain a better understanding of the ideas.	Share ideas about what they know with their peers. Answer questions and engage in discussion. Listen and comment on peers' ideas. 15 min

Ask students to further consider the W column. What do they need to know in order to answer the guiding question or respond to the topic idea? Give students 5 minutes to think individually, then ask them to group with 1-2 others and share ideas with one another. As they share with one another, walk around the room and observe their comments.	Individually, brainstorm and list ideas in the W (what I want to know) column in response to the guiding question or topic. Group with 1-2 other students to share ideas. Record ideas in the W column in the KLEWS Chart. 10 min
Guide students to identify questions that are relative to the upcoming inquiry investigation through a class discussion. Add these questions to the class W column. Encourage students to revise/add to their own KLEWS chart. Prompt students to identify Science Concepts that can be added to the S column.	Verbally share ideas with the class about what is needed to be able to answer the question or address the topic. Revise and add to the KLEWS chart. 10 min
Tell students that they will have the opportunity to answer some of their questions listed in the W column. Ask them to record observations and evidence in the E column of their chart. (2)	Make brief notes about the types of observations or evidence they might record. 2 min
Lead students through the inquiry activity (3), facilitating in a way that is appropriate for the activity.	Engage in the activity using appropriate lab materials. As needed

Facilitate class discussion to create a consensus on the evidence and observations from the inquiry activity. Record these in the E column of the KLEWS chart. Add vocabulary (4) and science concepts to the S column as appropriate. Complete the L column with the class findings from the inquiry activity. What inferences can be made based on the evidence collected?	Share findings with their peers. Revise and add to individual KLEWS charts. Use the collected evidence to make inferences about the topic or to answer the guiding question. Share ideas verbally. Write them in the L column, for what you are learning.
	20 min
Present a CER framework (5), where students write their Claim (answer to the guiding question, information from the L column), present Evidence (from the E column), and connect the evidence to the claim by using science concepts and appropriate vocabulary as their Reasoning (from the S column). Ask students to write their explanation (including claim, evidence, and reasoning) using the CER framework and the information on their KLEWS chart.	Complete a scientific explanation from the information on the KLEWS chart. Use a CER framework, with the C corresponding to the L column, the E corresponding to the E column, and the R corresponding to the S column.
	20 min or more
Allow students to share their ideas verbally (6) or by reading 1-2 other written explanations.	Listen to and critique other explanations, if shared verbally. Read and critique 1-2 other student explanations. (7)
	10-60 min
Total duration in-class = Minimum 120 min but can be up to 3+ hours depending on the inquiry activity used.	

Notes

(1) Guiding questions can be simple or complex. You can create a guiding question that lends itself to one "correct" answer or many justifiable answers (with no clear correct answer).

(2) This is an opportunity to review what constitutes evidence, different types of evidence used in science, and the difference in observations and inferences. New understandings can be listed in the "What am I Learning" column.

(3) The inquiry activity can be set up in many ways. It could be a traditional cookbook style laboratory, with a set procedure and method as is common in many university laboratory settings. It could be an open-ended investigation planned by the students to answer their individual questions in the KLEWS chart, which is consistent with an independent research project. Many times, we use investigation stations where students rotate to complete several shorter experiments or activities that illuminate the ideas being studied. It is also important to know that the inquiry activity can be a wet lab paired with other sources of evidence, such as readings or expert lectures. This can look different based on the nature of your content and discipline. Anything that allows students to compile evidence of some kind is appropriate.

(4) Use this time to introduce vocabulary words that students may not already know. "Just in time" vocabulary acquisition can be very powerful. If students begin to describe a concept but do not know the appropriate terms, it is appropriate to put that term in the S column of the KLEWS chart and ask them to write the definition.

(5) Many different types of CER graphic organizers exist, with varied levels of scaffolding (McNeill & Krajcik, 2012). Students can craft a written CER explanation, or they can prepare some brief speaking notes by highlighting and drawing connections directly on their KLEWS chart. Explanations can be shared verbally or in written form. Figure 35.2 shows a KLEWS chart with notes corresponding to the CER framework for writing an explanation.

(6) By asking students to engage in verbal discourse as they share and critique their developed explanations, it is possible to stretch this activity into the practice of scientific argumentation. Students can also refine their explanations through this authentic process. The time you have to devote to this step could likely be the determining factor on the depth you pursue, but students should be allowed time to minimally read one other explanation, critique one another, and also gain perspective on their own work.

(7) Critiques can be made orally or in writing.

35.5 Top Tips for New Instructors

1. When implementing this activity, try to use an investigation or lab activity that you are already comfortable using in your classroom or lab setting. After you become accustomed to using the KLEWS chart, you can modify and adjust your

K (what I **K**now)	L (what I am **L**earning)	E (**E**vidence & observations)	W (what I **W**ant to know**)**	S (**S**cience concepts)
	The **C**laim can usually be found here or as an answer to the guiding question.	**E**vidence is found here, and should include 3-5 observations to support the **C**laim.		Use the science concepts listed here in the **R**easoning as you explain why and how the evidence connects to the claim.

Fig. 35.2 KLEWS Chart featuring CER Framework, based on Hershberger & Zembal-Saul (2015)

activity to make it more seamless. This is meant to scaffold and support student in introductory classes as they begin to communicate scientific claims justified with evidence, so it likely not be used for every activity in a course as students become more proficient.

2. While leading the class discussion throughout the process of recording and sharing information on the class KLEWS chart, it might be helpful to ask a student to record on the large chart while you are free to move around the room and engage all students.
3. Think through your inquiry activity, and create your own KLEWS chart prior to doing the activity with your students. Think about the important "K" column prior learning that you expect students to have. Identify some ways you can question students to elicit these ideas if they do not come up with them organically. Identify some misconceptions students may have, and prepare questions to create cognitive tension. Think of ways you can lead the students to put these questionable ideas in the "W" column because they want to know more. Identify ways you can facilitate during the inquiry activity so students are prompted to include appropriate observations and evidence as they complete the activity. Students may need to be provided with an additional data sheet or scaffolds to enable data collection and observations.

References

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Website Links

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RADAR Framework for Evaluating Sources of Information

36

Kari D. Weaver, Kate Mercer, and George Lamont

Investigating - Organising - Arguing

36.1 Learning Outcomes

By the end of this exercise, learners will be able to locate, critically evaluate, and use scholarly information to facilitate research that inspires and helps each individual succeed academically and professionally.

36.2 Teaching Context

The RADAR (Relevance, Authority, Date, Appearance & Accuracy, and Reason) lesson and exercise presented here have been used for several years to teach students in our science communication courses. These courses are designed for first-year undergraduate students in STEM programs including biology, chemistry, physics, aviation sciences, environmental sciences, and engineering at our large research university in Canada.

This lesson generally comes early in the term to equip students to seek and select credible sources about a project. The presented teaching activity can be used as a stand-alone lesson or integrated into a scaffolded approach to support students as they prepare a research-based paper or project. The RADAR framework scales to

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handle increasingly complex information; as such it can be used throughout the curriculum at the undergraduate and graduate levels.

36.3 Overview of the Teaching Activity

The RADAR activity provides a framework that gives learners a consistent, methodical approach to the critical evaluation of information. The acronym RADAR enables students to consider the quality of any information source (Mandalios, 2013).

In this activity, the RADAR framework is paired with active learning and discussion-based pedagogical approaches to teaching critical evaluation of information. The active-learning elements are rooted in real opportunities for students to find and critically appraise information pertinent to real-world problems of interest.

Further skills in contextualizing research motivation can be developed with the CARS model of scientific and engineering introductions (Swales, 1990). The discussion-based pedagogical work focuses on typical student approaches to information seeking, primarily the tendency to rely on a single point of information gathering, typically a simple Google search, along with discussing how information is needed and used throughout the scientific process to generate, shape, contextualize, and iterate scientific discovery.

36.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Introduce learning outcomes and set class expectations for participation.		Slide deck 2 min
Present the class with 3-5 images to represent major scientific concepts, discoveries, or theories (1). Begin discussion by highlighting how the scientific process begins with an idea and then to begin to engage students by asking them to guess which ideas are represented by the images on the slide.	Guess the scientific ideas represented on the slide. This is a warm-up.	Images of scientific concepts, findings, or theories. 10 min

Introduce the concept that ideas are shaped by background information. Ask students "Where do you go to find information?" (2). Ask students what happens in the scientific process after finding information. Prompt questions include "How do you come up with an idea? How do you know what we already know about your idea?"	Discuss their existing practices for and attitudes towards information-seeking (3).	 5 min
Instruct students to complete a sample search on any topic from a science class using Google and a general library database (e.g., Scopus). Encourage them through giving real-time feedback by walking around the classroom.	Complete a search about any topic from a science class using Google and a library database (4).	Internet-enabled devices. 8 min
Provide students with a real-world problem and ask them for their "first impressions" yes/no answer (5).	Provide their yes/no answer to the real-world	Real-world problem. 5 min
This yes/no answer can be preliminary. Let students know they can reconsider later (to reduce their anxiety and keep the conversation moving).	problem question.	
Provide students with a short sample article that has some relevance to the real-world question (6). Explain the source is provided to help them make up their mind about the yes/no answer above. Have students read the article with the intention of responding yes/no to the question "Is this a good information source?" Ask students for (i) their yes/no response and (ii) one reason to justify their response. Ask "Is your reason for making the yes/no choice enough to justify the source quality?" (7). As a group, consider what the responses mean for bias in information.	Read the sample article and make a yes/no determination about whether the article is a good information source. Discuss why they made their yes/no appraisal. Give ONE reason to justify their choice.	Sample article used for discussion (6). 15-20 min

<table>
<tr><td rowspan="2">Introduce the RADAR framework and highlight the particular importance of relevance (8,9).</td><td rowspan="2">Use the RADAR worksheet to apply RADAR to the sample article.</td><td>RADAR worksheet</td></tr>
<tr><td>15 min</td></tr>
<tr><td rowspan="2">Ask students clarifying reflective questions:
“After applying RADAR, what is your opinion of the sample article? How was the article written? What does this tell us about the reason for the article’s existence?”
“What does this analysis tell us about how to tell “good” from “bad” sources?” (10)
“Did you have any difficulties making RADAR-driven decisions?”</td><td rowspan="2">Give ideas.
Respond to questions.
Ask clarifying questions about applying RADAR or using information.</td><td></td></tr>
<tr><td>10 min</td></tr>
<tr><td colspan="3">Extension –
Students independently investigate a second source and evaluate it for credibility with RADAR. The student products demonstrate facility with applying the model in new situations. Students can also peer-review each others’ RADAR analyses.</td></tr>
<tr><td colspan="3">Extension –
This lesson can support iterative research-oriented assignments. The next step can be a project pitch where students include RADAR analyses of at least one chosen source. As the course and project continue, students can then submit an annotated bibliography. The bibliography can be assessed for evidence that students are evaluating their sources for credibility. Grading with RADAR criteria creates continuity in the students’ learning process and allows the instructor to observe students’ consistency in using RADAR to assess data sources.
The project can further evolve with a literature review, a class project presentation, and a final proposal or article. Each product iterates students’ use of RADAR and can be graded with RADAR criteria. This iterative process trains students to use RADAR as standard practice.</td></tr>
<tr><td colspan="3">Total duration in-class = 70 min. Class time may be streamlined to 50 minutes by assigning the sample article as a reading prior to the class.</td></tr>
</table>

Notes

(1) Possible ideas include Dolly the sheep, insulin, and light waves. Focus on easy guesses around topics that link with students’ areas of study.

(2) We encourage users of this lesson plan to encourage students to be honest—even if their honest responses are not the academic ideal. Using phrases such as “I know you Google it, that’s ok, just tell me how you use Google” relaxes

students and encourages them to open up. This candour makes it easier to prompt students to perceive the pitfalls themselves and use better sources through their own decision-making.

(3) Prompting students to pause and observe their typical behaviour is a significant emphasis of this lesson, which grounds how they will understand the RADAR framework. When we conduct this lesson with less time spent on student reflection of their current practices, it is less successful.

(4) Help students become aware of the different results they can get (which depends on where and how they search).

(5) Example problems include things that are presented in the media (e.g. vaccination compliance), things related to workplace examples (e.g. corporate-issued wearable fitness trackers, self-driving cars), or things that are more scientific (e.g. Dolly the cloned sheep). Choose something that will interest your students.

Your goal is to ask the students to answer a question with a yes/no answer, but importantly the answer should actually not really lend itself to an absolute yes/no. Example questions include "Are vaccines safe?"; "Is it OK for an employer to ask their employees to wear a fitness tracker?"; "Should a self-driving car ever be allowed to hit a pedestrian?"; "Should we clone animals?" Focus on containable problems—the goal is to give them real-world examples, in a relatively tight timeline (50–70 min). Try not to get the conversation into deeply philosophical territory, because this takes a lot of time and distracts from the goal of the class (which is ultimately to critique the source).

(6) Use a short sample article. Given the time it takes differently abled readers to process something new, no longer than 1000 words is preferable. While the lesson plan presented suggests providing a sample article, students can be directed to identify their own articles to read and use for discussion. We typically use this approach in upper-level undergraduate courses or in lab settings with additional time.

(7) Students usually give answers here that relate to one piece of information and/or their personal experience. The answer to your question here is "no". The single reasons are not sufficient or necessarily credible without further review, consideration, or backup. This discussion helps students understand the need to critically evaluate information.

(8) Distribute RADAR handout/activity sheet at this time.

(9) Students often select information sources they find easily, rather than choosing the most relevant sources. It is important to emphasize that "relevance" is a more important criterion than "found first". By using RADAR, students can give structure to their thinking. RADAR still allows for personal perspective, but it encourages students to systematically frame their search and source critique behaviour.

(10) "Good" and "bad" are subjective, determined by purpose, and very hard to discern. A more useful designation can be "unbiased" and "biased".

36.5 Top Tips for New Instructors

1. This lesson is designed to facilitate an open discussion with students about information. This guideline and suggested approach are intentionally flexible for use in varied classroom contexts and timeframes.
2. Resist the inclination to just teach students where to find good sources. The goal of this lesson is to foster student-centred critique of their sources—ultimately, it should be their own idea to use library catalogues or other more academic sources. Teaching "library searches" often create passive learners who apply externally imposed practices. Teaching "critique" helps students internalize the practice.
3. This lesson is mainly guest-taught in our science communication courses by a librarian. A practical option for effective instruction is to arrange a partnership with a librarian at your institution.
4. The lesson works best when students interact with others to assess information. We find students learn as much from their peers as from us. Significant learning occurs when students debate what makes a source good, whom they trust and why, and why they use particular sources.
5. This class is most successful when the students both guide and drive the conversation. Engagement leads to changes in practice.
6. This lesson can be engaging online. Include small-group discussion and peer-to-peer learning. For asynchronous teaching, use discussion boards, classroom chats, and shared documents to enable interaction.

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Further Reading/Exercises

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Kate Mercer is a STEM Librarian and Adjunct Professor in Systems Design and Biomedical Engineering at the University of Waterloo where she teaches communication. Kate completed her PhD at the University of Waterloo's School of Pharmacy in 2019, which focused on medical decision-making. Her current research addresses how STEM students access, understand, and disseminate information.

George Lamont is a faculty member in the University of Waterloo's Department of English, teaching first-year STEM communication courses for the Faculty of Science. Teaching science communication online and in-person is one of his specialities. His current research focuses on how science communication pedagogy changes student skills.

Forming an Effective Research Question 37

Marie McEntee and Nicolette Rattenbury

Investigating - Arguing - Distilling

37.1 Learning Outcomes

Research questions are foundational to scientific inquiry. This activity assists students to create an effective research question to guide their intended science investigations. It also provides teachers with early insight into student reasoning and research capabilities. On completion, students will recognise question-making and refinement as a critical step in scientific inquiry and communication. They will learn to think critically about their research questions and apply this understanding to their current and future science investigations to enhance research design, implementation and communication.

37.2 Teaching Context

We use this exercise in an undergraduate first-year science communication class. This activity is taught in the first week, as writing an effective research question is foundational to our course's assessment (an abstract, poster and oral presentation, all based around one research question). To be an effective communicator, students must present a logical, robust and defensible argument guided by a quality research question. The activity can also be applied to any science course and is suitable for

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teaching postgraduates to develop research and communication capabilities and guide dissertation or thesis research.

37.3 Overview of the Teaching Activity

The activity is divided into two parts. In Part 1, the instructor develops an example research question and uses this to identify keywords to undertake a preliminary search of a library database and refine the question. The activity identifies characteristics of an effective research question.

In Part 2, students work with a self-selected topic to (i) develop an effective research question, (ii) identify searchable keywords and (iii) undertake a basic search of the library databases to find relevant documents and refine their question.

The activity is underpinned by a constructivist approach to teaching and learning which facilitates student engagement and the co-construction of ideas to encourage critical and independent thinking that is recorded on a worksheet. This activity prepares students to confidently undertake their own independent research.

Two extension activities are also outlined: (i) to enhance students' numerical literacy as they find appropriate and question-relevant quantitative evidence in library resources and (ii) to provide an opportunity for students to gain feedback on their final research question and selected resources.

37.4 Runsheet and Lesson Plan

Students come to the activity with a 'topic of interest' they wish to investigate during the course (1).

Instructor does…	**Students do…**	**Resources**
Part 1		
Provide students with worksheet (2). Outline activity objectives (3). Show examples of assessed coursework so students can see communication outputs that rely on this activity (4). Ask students to work in pairs to identify one purpose of a research question. Write suggestions on whiteboard (5).	Read or write activity objectives in worksheet. In pairs identify one purpose of a research question. Write class suggestions on worksheet.	See (2) Whiteboard or prepared instructor slide Worksheet for students Website links (1) for examples 5 min
Ask students to write down their self-selected topic and reasons why they are interested in this (6). Display a topic of the instructor's choosing and a list of possible sub-topics for investigation (7).	Write their self-selected topic and reasons for interest. Copy instructor's topic example and sub-topics onto worksheet.	Worksheet for students Whiteboard or prepared instructor slide 5 min
Select one sub-topic and display two research questions that could be used to investigate the sub-topic - one good and one poor (8).	Suggest characteristics of an effective research question.	Whiteboard or prepared instructor slide

Use class discussion to explore which question is good, to identify characteristics of an effective question. Place characteristics on whiteboard (9).	Write class suggestions on worksheet.	Worksheet for students 10 min
Use the 'good' question to circle keywords to search for documents in a library database. Ask students for other keywords that could be used as alternative words in a library search. Consider also truncations (10).	Copy the 'good' question example to the worksheet and circle the keywords. Provide verbal feedback on alternative words and truncations and write these on worksheet	Whiteboard or prepared instructor slide Worksheet for students 5 min
Access library database and display through data projection (11). Use the good question's keywords to find relevant library documents (12). Choose one interesting document from the results. Open and scan the abstract for relevance (13).	Watch, listen and write any notes in the general notes section of their worksheet.	Data projector for instructor Worksheet for students Database-specific videos (14) 8 min
Verbally refine the question to create an effective research question and discuss its quality (15).	Write down the revised question in the worksheet.	See website links (1) for case study 2 min
Part 2		
Ask students to develop their own question from their sub-topic,	Work individually to devise a question for their sub-topic and circle the	

circle keywords, consider alternative words and truncations.	keywords. Write this on the worksheet. Form pairs and discuss the quality of their question based on the criteria previously identified. Identify alternative searchable keywords.	10 min
Encourage students to begin their initial database search using their keywords to find one relevant document. Refine the question to make it more specific to the chosen document. As the question is refined, encourage students to enter more specific keywords from their refined question, to find further relevant documents.	Circle the keywords in their question. Access the library database and search using keywords to find relevant documents. Assess suitability of the returned documents. Begin refining their question. Write their question and copy links to any documents on their worksheet to record their work for future reference.	Computer access for students 10 min
Close the session, encourage students to complete their worksheets and continue their research out of class.	Complete worksheets. Undertake comprehensive and detailed searches outside of class, refine their question as appropriate and post online for further comment.	 5 min
Extension 1 – Quantitative data		
In this extension the instructor provides documents that contain quantitative evidence that is relevant to the research question. The class, as a group, can examine the papers and discuss whether particular data address the given research question. Ideally, some examples should answer the research question, while some should not (16).		

Encourage students to find data that answers their research question outside of class. They can post their research question and data online for feedback (see extension activity 2)
Extension 2 – Instructor and peer feedback
In this extension, students submit their final question and links to a small sample of documents to a course-restricted online platform (17). Students provide constructive feedback on classmates' questions and documents, while instructors endorse student feedback or provide further helpful advice.
Total duration in-class = 60 min workshop (Part 1 and 2) in a computer room; OR Part 1 as a 60 min lecture (times increased to allow more discussion) and then Part 2 and Extension 1 as a minimum 40 min lecture-workshop. Extension 2 can be completed out of class. While board-work ideally promotes co-construction, where time is limited, use prepared slides.

Notes

(1) Topics must be focussed, e.g. 'health' is broad, while 'diabetes' is focused. Our students choose any topic relevant to their subject major.
(2) The activity worksheet can be downloaded from website links (1).
(3) We emphasise: (i) Understand importance and purpose of research questions to science research; (ii) identify characteristics of an effective research question; (iii) develop research question-making and refining skills; (iv) develop or enhance database searching skills; (v) develop research capabilities.
(4) See assessment examples from our course in website links (1).
(5) We emphasise (i) foundational to the research process; (ii) provides direction and focus to the investigation; (iii) assists the literature search.
(6) By asking students what they find interesting about their topic, you can help them reveal sub-topics.
(7) Sub-topics may include impacts or effects (social, economic, cultural, biological, physical), processes (social, biological, natural), theory (e.g. contrasting views); applications including cases or populations, comparisons, efficacy and management approaches.
(8) Initial questions are used for keyword development and will likely need refining after the library search. Students still need to be encouraged to develop a good question at this stage to provide meaningful guidance to their library search.
(9) We emphasise (i) not too broad or too narrow; (ii) suitable for student's ability—not too difficult or easy to answer; (iii) an open rather than a closed question (why, how, what questions, rather than can or do); (iv) leads to analytical rather than descriptive investigations; (v) clearly written and avoids asking multiple questions in one question; (vi) generates results from a database search.

(10) Alternative words and phrases for keywords and truncations (i.e. impact* rather than impacts) are useful for searching databases, when the original search doesn't find enough information or must be narrowed. For example, climate change (global warming, environmental change); OR marine life (fish, whales); OR impact (effect, influence).
(11) We recommend SCOPUS and Google Scholar; however, instructors can use any database.
(12) When scanning the list of documents, instructors should articulate their thinking about how they choose appropriate documents (see Top Tips #7). We encourage students to find journal articles, but at this stage do not limit the search. However, do teach students how they may refine their search and results at a later stage, by altering the search parameters.
(13) Eventually students will read the entire document, but at this stage the document's abstract gives quick insights to the content.
(14) We provide a video on accessing specific library databases for students to use after class. Ask librarians for videos.
(15) Emphasise that questions are refined based on the literature search or even substantially changed as students discover a document that stimulates a new interest. This refinement may create new searchable terms to find other relevant documents. See website links (1) for a case study about question development and refinement.
(16) When assessing appropriateness of quantitative data, we emphasise: (i) Are the data misleading? Data presentation should be fair and avoid choosing data for the wow factor; (ii) are sources reputable particularly if using websites?; (iii) relevance—does the data answer the question or just mention some of the keywords?
(17) We use Piazza. Our students value feedback as they recognise that the research question is foundational to their ongoing assessed coursework.

37.5 Top Tips for New Instructors

1. The worksheet is an essential learning tool where students can keep a record of the activity and their ongoing progress.
2. Students should think of themselves as investigators—a bit like a detective or a research scientist.
3. Procrastination around question-making is a problem for some students. Students need to create effective and workable questions, and not keep searching for the 'perfect' question. They must begin this process early. Extension 2 in the lesson plan encourages student action, provides support and identifies procrastinators.
4. Have students work together in the activity as much as possible to build confidence and co-create ideas.
5. Using examples of past student coursework shows how research questions underpin science investigation and communication. See website links (1) below for examples from our course.

6. Be prepared for the database search, so you know what documents will appear and can choose documents familiar to you.
7. When undertaking the database search, articulate your thinking to develop student research capability and enhance academic integrity. Some interesting questions are: Why did you choose a document (relevance, interest, accessibility)? What if your different documents do not agree? We encourage students to find and use documents that reach different conclusions, as scientists often do not agree; discuss the different article types (e.g. experimental, literature review, meta-analysis, content analysis) and types of evidence—quantitative or qualitative.
8. Allow as much freedom as possible in topic/sub-topic selection to stimulate independent and critical thinking. Topics that are personally interesting to students make investigation enjoyable. However, prevent students from setting out to prove any pre-held biases or discriminatory views.
9. Ideally, have tutor support to assist students, particularly for Part 2.

Website Link

Teaching Resources provided by authors for the lesson-plan. (http://www.mariemcentee.nz/teaching-resources.html). *Accessed 28 Jan 2021.*

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Part VIII

Practice Storytelling

The Hero, the Villain, the Goal, and the Resolution: Using Narrative Arcs to Improve Science Presentations

38

Susan Rowland

Storytelling - Speaking - Distilling

38.1 Learning Outcomes

Students often have difficulty understanding that science can form the basis of a story. This exercise introduces them to the idea of science-as-story. The exercise is especially important for students who are presenting their research. By the end of this exercise, students will be able to define the hero, the villain, the goal, and the resolution of any story. The exercise helps students reframe how and why they are presenting information. It also helps them increase audience engagement with their presentation because they are able to articulate the "so what" in any communication event.

38.2 Teaching Context

The activity helps speakers define the protagonist, conflict, and goal in their work. It is a very different way for science students to think about presenting science, but it is also very illuminating for them. It starts productive conversations where people help define the hero and villain for their classmates.

I have used this activity to help PhD students reframe their 3 Minute Thesis talks (3MT), but it can be used for any science communication event—it would also work for students who are preparing a paper, a poster, a press release, or a grant.

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It can be done in 1 h (abbreviated form) or in a longer 2–3-h workshop or in two workshops (pre- and post-rebuild of the presentation). I have taught it online and in-person. It could be used for students at any level of education.

38.3 Overview of the Teaching Activity

The first part of this exercise introduces students to the idea of a narrative arc and the characters in the story that drive the arc. We use the story of Cinderella as a starting point. We begin with the understanding that Cinderella is a good story, because it has a clear hero, villain, goal, and resolution. We discuss the hero and villain of the story; students can define them as Cinderella and the stepmother/stepsisters. We map the narrative arc of Cinderella using Time on the X axis and Cinderella's Happiness on the Y axis. Students then work to define the hero's goal and the resolution of the story.

After this, we turn to the stories that students want to tell. If the students already have short talks available, they can present some of them to the class (as a "pre" exercise). We then work to define the hero, villain, goal, and resolution of these stories using a conversational approach. Students write a short script about their characters and narrative (or rewrite their short talks) and practice speaking these to the class (as the "post" exercise).

38.4 Runsheet and Lesson Plan

In this lesson plan, the students' activity is a 3 Minute Thesis (3MT), but the plan and notes are broadly applicable to any other communication activity. It is important that the students share their ideas with each other, so you will need to adjust the time in the runsheet for them to do this in some way.

Instructor and students do…
Introduce the concept of narrative arc, hero, and villain (10-15 min)
Instructor Explain the purpose and wider application of the exercise. Ask the students if they know what a narrative arc is (1) and lead group is discussion of the narrative arc as a storytelling tool. Use the diagram to explain the contributors to a narrative arc, including the hero, the villain, the goal, and the resolution. *Students* Make suggestions about their understanding of narrative arc. *Resources:* Diagram of the key parts of a narrative arc (2).

Instructor Introduce Cinderella as the focus of this part of the lesson and as the test case to illustrate the narrative arc concept. Give a very short description of the Cinderella story (or ask students to help explain the story) (3). Ask students about the hero, villain, goal, and resolution components of Cinderella. *Students* If requested, help explain the Cinderella story. With instructor, decide on the hero, villain, goal, and resolution of Cinderella. Resources: Whiteboard for facilitator
Instructor Ask students to draw the narrative arc of Cinderella from Cinderella's perspective (4). *Students* In small groups (2-4), do the drawing (~3 minutes) then share with the class (~2 minutes). Resources: Paper or whiteboards and coloured pens for students (5).
Prepare or examine student talks (20 min)
Optional (20 min) Students share their 3MT or other short talk (6) *Resources:* 3MT competition at your university. Place to present with projector or other mode to share visual components of talk.

Instructor Ask students to look at their own current or planned presentation and define key components (the hero, villain, and goal) (7). After students have defined their hero, villain, and goal, you can then facilitate discussions to help students solidify their ideas around the resolution (8). *Students* Think about their own presentation and define the hero, the villain, and the goal. Share in small groups/pairs. Report back to group. After this, consider the resolution to their story. *Resources:* Materials to write and draw.
Rebuild talks and practice (20 min or more for rebuild plus enough time for all students to present their story) (9)
Instructor Facilitate conversations if students desire them. After students have rebuilt their talk, facilitate presentations. *Students* Rebuild 3MT script using revised characters, goal, and resolution (9). Then, practice to the class.
Resources: Space to present, with projector.
Total duration in-class = Minimum 60 min but can be up to 3 hours or two workshops each of ~2 hours. Time depends on size of class and length of presentations.

Notes

(1) Read some resources about narratives so you are prepared for the discussion. There are a lot of great diagrams of narrative arcs online. See Website resources for useful examples.
(2) You can spend more time on other elements of the narrative arc if you want to (e.g. rising action), but it's not necessary at this point
(3) Use the simplest version of Cinderella—the modern Disney version. Students don't know the original Grimm version, and there are a lot of variants of the story that don't follow the simple narrative arc of the Disney Cinderella. If you want to expand this exercise for science communication students, looking at other versions of Cinderella can be instructive, because some are long-winded and confusing.

(4) Use an X-Y axis with Time on X and Cinderella's Happiness on Y. This is not supposed to be a long process; just do it quickly to cement the idea of the narrative arc.
(5) The arc from Cinderella's perspective is more correctly called a character arc, but for the purposes of this exercise, it's simpler to call it a narrative arc. See Website resources for a diagram.
(6) I do this workshop with students who are competing in the 3MT competition, so they already have a presentation prepared. If students have already written a short talk, this "pre" exercise is really valuable. Do this BEFORE students think about the hero and villain of their own piece. Call for volunteers, or ask everyone to do it, depending on the needs and size of the class. It works well if you put one student at the front to describe or practice their science presentation; then, open the floor to conversations about the hero, villain, and goal of the story. Students are supportive of each other, and they propose a lot of interesting ideas.
(7) At this point, adapt to whatever presentation format the students are using (e.g. abstract, talk, thesis introduction, etc.). You don't need to address the resolution in the initial discussion—students really struggle with defining the hero, villain, and goal of their story. The resolution becomes obvious after they have defined these things.
(8) Once students have established the hero, villain, and goal of their story, they can see the resolution more clearly. Now is a good time to talk about the resolution they can use to finish up their presentation.
(9) Depending on available time, this rebuild can happen in or outside of the workshop. Doing the rebuild collaboratively is very helpful, because students can talk with each other about their ideas for the hero, villain, goal, and resolution.
(10) This presentation is key. It can take another full workshop if everyone would like to present.

38.5 Top Tips for New Instructors

1. Students are surprised that all stories have a hero, a villain, a goal, and a resolution. They get into a lot of interesting discussions about the hero's goal in Cinderella. Is it love, freedom, marriage, or revenge? The goal can be interpreted in many ways. You can help by saying, "Oh, that's an interesting perspective—what do others think?" Through this conversation they learn that it's OK to have an opinion and express it.
2. In considering Cinderella, students begin to realise they must draw on pathos (appeal to emotion) when telling a story. Cinderella "works" because people care about the hero and can readily identify the villain. Students translate these ideas to their own science stories; this makes them think about how to get the audience to care about science stories (and their heroes).

3. Do not just identify the hero, villain, goal, and resolution for the students in any of their stories. Leave them to puzzle over it. Write options on the board as they think and make suggestions. Help them come to a group decision about the components of the story.
4. Students often strike problems when they come to identify the hero and villain of their own story. Before they do the exercise, they can hold a conceptualisation of their story that doesn't make sense. During the exercise students may discover that their nominated hero and villain are not actually working in opposition to one another (i.e. their "hero" is not a character who is pursuing the goal and the "villain" is not a character who is working to thwart goal attainment). This means they need to reconceptualise the characters of their story and the goal, before they can work on finding a resolution. They may need to go home and think about this and prepare their revised talk for another day.

Website Links

A useful site about narrative arcs. (https://blog.reedsy.com/narrative-arc/). *Accessed 20 Dec 2020*.

A useful diagram for Cinderella you can use to sense-check the students' drawings. (https://www.eadeverell.com/character-arc/). *Accessed 20 Dec 2020*.

To run a 3MT program at your university, contact The University of Queensland (https://threeminutethesis.uq.edu.au/) for permissions and resources.

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A Practical Guide to Storytelling Frameworks

39

Amanda Niehaus

Storytelling - Writing - Distilling

39.1 Learning Outcomes

Scientists at all stages—from undergraduates to centre directors—struggle to write effectively. Writing is one of the hardest things we do as professionals: it asks us to frame our ideas in ways that connect with unseen others who likely differ in values, motives, and knowledge. As writers, we must know what we want to say while empathising with readers to ensure that we say it clearly. This takes significant effort, which is why so many scientific papers are frustratingly dense. After completing this exercise, students will be familiar with the basic formula for all good stories, enabling them to observe stories in their everyday lives and apply the story formula in any writing or speaking context.

After completing this exercise, students will be familiar with the basic formula for all good stories, enabling them to observe stories in their everyday lives and apply the story formula in any writing or speaking context.

39.2 Teaching Context

This activity works best in-person, where I find that students are more open and engage more readily with each other. However, it also works online. The activity can be used at any level, but because understanding and telling stories are highly transferable skills, the earlier they can be learned, the better. I usually run this

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activity as a half-day workshop (3–4 h), but it can be split over shorter sessions, and the abstract-writing component can be assigned as out-of-class work.

39.3 Overview of the Teaching Activity

We begin by characterising stories and identifying their key structural components. Fundamentally, stories describe a change in circumstances: something disrupts the status quo, causing something different, contradictory, or unexpected to happen. In the first part of the activity, we look for these “and”, “but”, and “therefore” moments in popular culture such as fairy tales, books, and movies. We then observe and apply the story framework in scientific writing.

39.4 Runsheet and Lesson Plan

Discuss: Stories are everywhere (5-20 min)

Ask students: Can you define what a story is?

Stories are the basis of all great conversation, entertainment, advertising, and oration—and once we begin to see them in our everyday lives, it’s difficult to un-see them. By thinking of scientific writing as a kind of story, almost everything that we experience can help us become better writers. But how do we define “story”?

Resources for the whole class: Whiteboard, computer, projector, whiteboard pens, coloured textas, writing or drawing paper for activities, movie clips.

Extension: Share fairy or folk tales (1).

Discuss: Basic story framework(s) (1 min) At the most basic level, every story has a beginning, a middle, and an end, and each part serves a particular purpose. *Draw:* Table with 3 headings—Beginning, Middle, End. The rows below will be filled in progressively.
Discuss: Beginnings (10-20 min) The beginning of a story is where the world is built, the characters introduced, and the important historical points communicated. We must establish the status quo—i.e. show what things were like before the norm is upset or conflict prompts change. *Write:* "Before" in the Beginnings column. As you go, you can fill in key words that signal the before in that column (e.g., information, status quo, "and", etc). *Show:* Film clip (2) *Discuss:* Film clip to exemplify what beginnings are intended to do *Ask students:* How do writers establish the *before* in your favourite books, movies, video games, or tv series?
Discuss: Beginnings in scientific writing (10-15 min) We must also establish the 'before' at the beginning of a research paper. The first part of the Abstract and the beginning of the Introduction should establish the state of the field as the researcher(s) found it. What do readers need to know about the history or context of the work to understand its outcomes and implications?

Run-through: Together as a class, examine the beginnings of 2-3 *Nature* abstracts (3)

Discuss: Randy Olson's *And.*

In his excellent book *Houston, We Have a Narrative* (2015), biologist and screenwriter Randy Olson calls this part of the story the "And", because the word "and" is often used to link informative statements.

Write: "And" in the top row of the table in the Beginnings column. (We will use this keyword later).

Ask students: Do any of the abstracts you looked at explicitly use the word *and* in those beginning lines? What other words take its place? Is *and* ever implied? (9)

This is a good place to introduce a break. If you are splitting the class over two sessions, ask students to look closely at beginnings of stories and bring some examples to share next time.

Discuss: Middles (10-20 min)

Write: "But" in the top row of the middle column of your table. Again, fill in any key words below that exemplify this part of the story (e.g. change, conflict, problem, however, etc)

According to Randy Olson, in a story, the "And" leads directly to the "But". But this transition needs to happen rather quickly, so audiences don't lose interest. Our brains crave a turn of event, a conflict or contradiction. So early in the storyline, something must change for the lead characters that upsets the established norm (e.g., a secret is uncovered, a deadline imposed).

Discuss: Turning points in *Inception* (4) or other movies/books of choice.

Show: Clip from film (5)

Ask students: What is a "turn" moment for Drs Sattler and Grant in *Jurassic Park*?; What are some of the ways writers set up the "turn" in your favourite books, movies, video games, or tv series? There are likely to be multiple storylines that emerge simultaneously or consecutively in any good fiction/non-fiction. A movie built on just one story would be way too simple.

Discuss: The "gap" in scientific writing (20-40 min)

Just as conflict or contradiction defines the middle of a story, the 'gap' sets up the premise of the research paper. What was incorrect or incomplete about previous work? What is the problem this study aims to solve?

Discuss: Abstracts or introductory paragraphs with too many *and*s and no *buts.* Either make up paragraphs or abstracts or find them in the literature.

Run-through: Together as a class, examine the general problem statement of 2-3 *Nature* abstracts. See Resources for link to the formula for *Nature* abstracts.

Ask students: Do any of the paragraphs explicitly use the word *but* to signal the gap?; What other words signal the gap?; Can *but* be implied?

This is a good place to introduce a break. Ask students to look at turns in stories and bring some examples to share next time.

Discuss: Endings (10-20 min)

Write: “Therefore” in the top row of the right column of the table. Fill in any key words below that exemplify this part of the story (e.g. resolution, consequences, outcomes, therefore, etc)

The end of a story explores the consequences of the *but* or change of circumstances. The car sped along the road, the tree fell—this is what happens after the driver swerves. This is the *Therefore*. What does the world look like now that justice is served or beliefs overturned?

Show: Clip from film. See if you can find an end-of-movie clip, like *Jurassic Park*, that’s not a spoiler.

Discuss: Endings of favourite movies/books/etc.

Ask students: What characteristics do the best movie or book endings have?

Discuss: The main result, and specific and general contexts in scientific writing (15-20 min)

Run-through: Together as a class, examine the outcomes section of 2-3 *Nature* abstracts. See Resources for link to the formula for *Nature* abstracts.

Draw: Nature abstract diagram. The *Nature* abstract is: (1) a layperson-accessible informational statement(s), (2) a more field-specific informational statement(s), (3) a gap, (4) a statement(s) about how the study filled the gap, (5) a field-specific statement(s) that contextualises the outcomes, and (6) a layperson-accessible statement(s) about the outcomes. This can be drawn as a decrescendo – gap – crescendo, where the ‘level’ of the statement at the end mirrors that at the beginning (> - <).

Discuss: It’s a common filmmaking technique to try to mirror the first and last images of a movie, so that they are reflections or inverses of each other.

Show: Video of first/last images in film. See Resources for a clip of first/last images of movies compiled by filmmaker and editor Jacob T. Swinney.

Discuss: and-but-therefore in practice (20 min or more) *Ask students:* Summarise a movie or book using only two lines: " __ and __, but __. Therefore __." (6) Can the others guess what it is? *This is a good place to take a break. Ask students to do the abstract exercise out of class or in the next class.*
Write: Students draft an abstract using the *Nature*/*and-but-therefore* framework, then exchange with a partner for comments/critique (20-45 min) (7) *Extension*: Pair students up with new partners and ask each to 'interview' the other and write their partner's abstract based on their conversation. I find that people often describe the context, aims, and outcomes of their work or ideas more effectively in conversation, rather than on paper. Begin with questions like: "What is the aim of the study?" or "What did you do?" and then reframe the answers (and any follow-ups) using the *Nature* abstract/*and-but-therefore* formula.
Total duration in-class = 3-4 hrs depending on number of students and participation levels. This can be easily split among shorter sessions

Notes

(1) Ask students to think about and share the fairy or folk tales they grew up with. This helps them get to know each other, so it's valuable to ask diverse students in the group (e.g. international students) to share. Hearing diverse fairy tales is so interesting. It reminds the students that they weren't all cultured in the same flask.

(2) I often refer to the movie *Jurassic Park* (1993), but you can pick something else. It's fun to show the clip before the discussion, in case some students haven't seen the movie. Near the beginning of the movie *Jurassic Park* (1993), for example, we meet Drs Alan Grant and Ellie Sattler in the field, just before their lives change forever. The timing is critical here: we need to see what regular old palaeobiology looks like—how dusty and mundane it can be, how much these scientists are asked to extrapolate from bones in rocks—so that when we arrive at John Hammond's new theme park, we can experience the marvel of living breathing dinosaurs through the eyes of people who have spent their careers studying dead ones.

(3) *Nature* abstracts are great for this exercise because *Nature* asks authors to adhere to a "story" formula—see Resources. I like to pick abstracts that relate to contemporary issues.

(4) Often, a new character is introduced, as in Christopher Nolan's *Inception* (2010), where young architect Ariadne (Elliot Page) joins Dom Cobb's (Leonardo DiCaprio) team of dream-infiltrators and makes it difficult for him to keep his secrets hidden. In this storyline, Ariadne's curiosity forces a change in Cobb's way of dealing with pain and fear.
(5) If you want, you could show another clip of a moment—there are a few to choose from—where Drs Sattler and Grant are thinking that maybe live dinosaurs are not all they're cracked up to be.
(6) Most movies, novels, etc. will comprise several stories that move sequentially or in parallel (i.e. subplots). When writing, it's easier to focus on one story at a time. If a story doesn't flow in the and-but-therefore framework, then they could be mixing elements of different stories.
(7) Drafting the abstract before writing the paper, essay, or report can help writers formulate the story more efficiently.

39.5 Top Tips for New Instructors

1. I always have stories of my own ready to share. By sharing something personal (like a favourite childhood book or a family legend), instructors can set a precedent for openness that makes this workshop welcoming.
2. Using clips from movies helps students see the *and*, *but*, and *therefore* in popular culture all around them, which reinforces what they learn in this workshop. Plus, it's fun!
3. Using multiple metaphors can help different students connect with the ideas and remember them more effectively.
4. Postgraduates and ECRs often feel that they haven't been taught to write grants or fellowship applications. It's worth discussing how the story framework used for *Nature* abstracts can translate to the summary or the first page of a grant application. What is the state of the field now? What is the gap? How will you, with your expertise and ideas, fill this gap?
5. Remind students to be specific when they describe information, problems, solutions, or outcomes. If they find it difficult to be specific, they might need to take some time to think through the story in greater depth or return to the *and-but-therefore* framework.

Website Links

Nature's abstract-writing instructions for authors. (https://www.nature.com/documents/nature-summary-paragraph.pdf). *Accessed 30 Jan 2021.*

First and last images of movies. (https://vimeo.com/122378469). *Accessed 30 Jan 2021.*

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The Five-Fact Story

40

Brittney G. Borowiec and Cathryn A. Freund

Storytelling - Engaging - Organising

40.1 Learning Outcomes

After completing this exercise, the learner will be able to:

1. Identify the parts of a story or narrative, such as conflict and setting
2. Evaluate what makes a compelling story or narrative and be able to apply these ideas to a science-based narrative
3. Create a structured written or oral story with minimal cues (3–5 words)

40.2 Teaching Context

This exercise is suitable for any level of undergraduate or graduate student studying any technical (STEM or STEM-adjacent) discipline. It works best when the facts and words chosen by the instructor are common knowledge and/or within the students' areas of expertise or current learning.

This simple and flexible exercise can be used as an introductory activity ("ice-breaker") or as a low-stakes assignment completed orally or in writing.

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Alternatively, it can be used as a pre-assessment review exercise to help students remember specific scientific processes or principles (e.g., the steps of photosynthesis).

40.3 Overview of the Teaching Activity

The Five-Fact Story activity is designed to introduce students to the basic principles of storytelling (see Table 40.1 for examples).

When planning this exercise, the instructor should consider the students' level of background knowledge about stories. If they are science students, it is likely that they have a relatively rudimentary knowledge of story structure. It is worthwhile priming students for the exercise by asking them what they know about stories and what makes a story engaging or effective. Students in other programs (e.g., communication) are likely to need less introductory discussion.

The activity begins by the instructor giving the students five random or pseudo-random facts or words (referred to as "words" hereafter). The activity is very flexible, so these five words can be random nouns and verbs, scientific terms that adhere to a theme (e.g., organic chemistry), or any other mix of words that the instructor chooses.

The student's job is to construct a story from these five words. They should be given a few minutes to think and then present their story to the class (but see below

Table 40.1 Examples of Five-Fact Stories using randomly generated words

Words	Example story
Potato chips, fork, soap, cat, book	I read in a **book** that if I gave my **cat** a bath with **soap** and combed his fur with a **fork**, he would give me a bag of **potato chips**. . . alas, the **book** was wrong, and now I have an angry **cat** and no **potato chips**.
Birthday, wine, parking, diplomat, complication	For my **birthday**, all I wanted was a glass of **wine** from my favorite fancy restaurant. Excitedly, I drove off. But when I got there, there was a **complication**: another vehicle rear-ended me as I was **parking** my car! The other driver got out, dressed in an appropriately dapper three-piece suit, introduced himself as a **diplomat**, and, as **diplomats** do, negotiated a fair repayment for the new dent in my bumper. . . **two** glasses of **wine** and his **parking** spot!
Ships, clouds, hyena, heat, carbon dioxide	Humans are putting more and more **carbon dioxide** into the air. This is causing climate change. It makes the atmosphere hold in more **heat** and threatens animals like the **hyena** with extinction. It is also bad for us: if more rain falls from the **clouds**, it could make our **ships** sink.

for alternatives to in-class presentation). After all stories are presented, the instructor should lead a discussion about which stories "worked" and which did not and why. Students will likely gravitate toward stories that were funny, or presented in an engaging way, or had a clear conflict and resolution.

40.4 Runsheet and Lesson Plan

Instructor does	Students do	Resources
Introduce the parts of a story to students or lead an interactive discussion on makes a good story (according to student experience level). Whiteboard the major parts of the story (or provide a PowerPoint slide) to act as a visual cue for students during the activity (1).	Participate in the discussion and/or listen to instructor's explanations.	Figure 1 5 min
Explain the Five-Fact Story and assign words to students (2).	Wait for peers to have words assigned. Review key parts of a story.	Tools (3) to generate and assign words 5 min
Keep time and assist students as needed. Some students may need help getting started. Instructor can suggest sentences that use words. Watch carefully for students' comfort and adjust time accordingly.	Think and develop stories. Students may wish to write their stories down before presenting.	Writing materials Time varies At least 2-5 min
Facilitate students sharing stories by calling on them individually (4, 5). Depending on time constraints and class size, it may be effective to remind the class of each student's words as they are introduced to emphasize what	Tell their stories to class. Listen to other students' stories and encourage peers.	

"checkpoints" they used to create their stories. Meet students with encouragement (e.g., applause) for their efforts.	Evaluate which stories they liked (e.g., top 2-3), and what features those stories shared.	20 min
Interactive discussion on what aspects of the stories were good and why, as well as how students could apply this activity to their own studies, work, or writing projects.	Participate in discussion. Share their favourite stories if prompted.	10 min
Total duration in class = about 45 minutes. Exact time depends on the number of students (or pairs/groups for classes larger than ~25) participants.		

Notes

(1) The two essential parts of a story are conflict and resolution. Conflict is a struggle between two opposing forces, such as characters with different points of view or a character and a situation, that create tension to drive the story forward. The actions of characters in a story can enhance, mitigate, develop, or be in reaction to the conflict. The resolution occurs when the conflict is "solved" in some way so that the tension is dissipated. Other common story parts or elements include setting (where the story takes place); characters (who is in the story); and tone (how the story is expressed by the author to communicate a specific emotional tenor) (Fig. 40.1).

(2) Options for customization at this step include selecting random nouns and verbs (beginner level); giving students >5 words so they can choose which ones work best for them to incorporate into their stories (beginner); selecting scientific terms that correspond to a topic covered in class (intermediate); restricting students' stories to a specific theme, such as climate change (advanced); or other variations suggested in the next section.

(3) Possible mechanisms include an online random word generator or a box filled with small pieces of paper with individual facts or words written on them for students to draw.

(4) Options for customization at this step include having students write their story and turn it in as a "low-stakes" class assignment or having students turn their story in as an infographic, comic, or other artistic medium. If the instructor

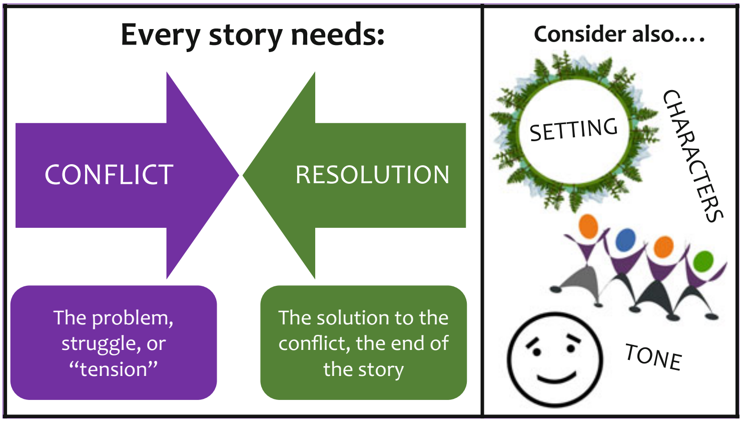

Fig. 40.1 The parts of a Five-Fact Story. Stories at minimum need a conflict and resolution. Depending on the students' story lengths, they could also consider building out the story's setting (where it takes place), characters (who is involved), and/or tone (the emotional tenor). Figure illustrations courtesy of openclipart.org

selects one of these options, the class discussion at the end of the activity could be expanded as part of the assignment briefing or saved for a later date. See the following section for more details.

(5) Related to the above, some students may find presenting to the class intimidating, or there may not be time for every student to present. Some options for these situations are to do small group sharing prior to having students present their stories (with the students choosing the "best" story in their group to share) or a think-pair-share type exercise.

40.5 Top Tips for New Instructors

1. The relatively simple setup of this activity means it is very flexible and can be modified to match student expertise, interests, and specific classroom objectives. For example, the words provided by the instructor can be key vocabulary terms in a science course (e.g., meiosis and X-inactivation for a genetics course). Instructors could also set limits on story length: a concise three-sentence story will be harder for science students to craft than a ten-sentence story.
2. There is also flexibility in how this activity can be incorporated into the course. For example, instead of an informal in-class activity, it can be a low-stakes written assignment or even a longer paper (e.g., create a one-page story incorporating the selected words or expanding on a classmate's story). Depending on instructor expertise or student goals and competencies, students could alternatively create an infographic or use another storytelling medium. We encourage instructors to experiment with their own variations on this core teaching practice to best suit their learning outcomes.

3. Good stories will have, at minimum, a clear conflict and resolution (Fig. 40.1). Depending on how long students make their stories, they could also focus on developing the story setting and characters. We suggest the instructor be familiar with the parts of a good story (see provided references below), that they review them prior to introducing the specific activity to the students, and that they demonstrate the activity or provide written examples for their students. We have provided examples of stories that instructors can use in demonstrating the activity at the end of this section.
4. Key discussion points during debriefing activities could include which story elements were the easiest to incorporate and which were most difficult; how a student's presentation style (e.g., cracking a joke or conveying deep emotion) influenced story enjoyment; how accurately students use specific scientific terms (if provided); and the implications of these choices in fields such science journalism.
5. Some additional considerations for inclusive teaching practices: (1) Some students will find presenting and public speaking challenging; perhaps offer an alternative to the current presentation structure; (2) emphasize to all students the importance of respect and maintaining a positive, safe space; and, if appropriate, (3) establish what topics are and are not acceptable to include in their stories (e.g., avoid potentially triggering or divisive topics).

Further Reading/Exercises

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Website Link

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Using the Message Triangle to Distil Complex Research into a Story

41

Kathleen M. Gifford and Mark A. Sarvary

Storytelling - Organising - Writing

41.1 Learning Outcomes

Students can use this versatile messaging tool to prepare various communications to engage their selected audiences with relevant information. A completed message triangle provides a foundation for a compelling story that the audience can relate to in environments ranging from the workplace to the dinner table.

After completing this exercise, students will be able to (i) critically think about the diversity of audiences and communication goals; (ii) evaluate scholarly information to be able to develop clear key points; and (iii) create a story by distilling complex scientific information. These are transferable skills that will benefit the students, regardless of the path they take after graduation.

41.2 Teaching Context

We have used this activity in many classes and workshops, both in-person and online. It is very discipline independent. We have seen undergraduates, graduate students and faculty benefit from learning how to distil complex scientific information into clear and organized stories using the message triangle. Students do not reinterpret the findings of the research; rather, they explore new ways for science to reach diverse audiences.

We generally use this activity towards the beginning of the semester. It helps students improve their reading skills and think about audiences, messaging and their communication goals. We find the conversations around defining audiences to be

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very illuminating as students begin to understand how defining a specific audience gives their communication more purpose.

The activity is an excellent foundation for storytelling, and there are plenty of opportunities to build on it with follow-up exercises.

41.3 Overview of the Teaching Activity

This is an active learning exercise, and therefore, student participation and peer interaction are essential components. Before coming to class, students need to read a peer-reviewed, primary research article. The article can be related to the instructor's discipline or the students' major. Using the same article for all participants is key, as students will identify many different ways to tell the same story.

In class, we start by asking students about their favourite stories. This exercise helps them begin to detach from scholarly writing and think about the prevalence of storytelling in our lives. It can be helpful to reference the basic elements of the story arc. Students brainstorm audiences to help them understand that a well-defined audience is key for effective science communication.

After a short introduction of the message triangle elements, students receive a printed or digital copy of the article and use it to distil the message and content of the piece. This is followed by a peer review or peer discussion to help students understand how many ways a scholarly article can be turned into a story. We ask the students to write a blog post, develop a Twitter thread or create a short podcast or vlog using the audience and the key points they identified in the triangle. These written or digital components also benefit from peer review.

41.4 Runsheet and Lesson Plan

Teaching how to turn a scientific message into a story for non-specialist audiences is a valuable skill for all scholars, regardless of the discipline or education level. It is an essential component of the science communication undergraduate course taught by the authors at Cornell University and at Shoals Marine Laboratory. This lesson plan has also been tested in a variety of workshops at the faculty and graduate student level. The allocated times can be adjusted depending on the level of student participation.

Instructor does…	**Students do…**	**Resources**
Pick a scholarly journal article that will be of interest to the class. It must be primary research and every student should read the same paper (1).	Read the assigned peer-reviewed primary research article prior to coming to class.	Article in electronic or paper form. See example article in references. 30 min
Pair up students for "think-pair-share" to discuss a favourite story. Ask for volunteers to share the story with the entire class (2).	Use think-pair-share to discuss favourite books, movies, and stories. Volunteers report back to the class.	Discuss the elements of the story arc. 10 min
Prompt students to think about the diversity of audiences and identify as many specific audiences as they can. Ask each student to report back ONE audience they would like to communicate to. Whiteboard the answers. Now, ask students if any audiences are missing. Write those down too.	Think about audiences. Report back the audiences they thought about (3). Importantly, each student should have the opportunity to speak.	Whiteboard and pens. 10 min
Introduce the elements of the message triangle (4). Provide a blank triangle and ask students to complete it based on the same journal article they have all read (5).	Find three main key points in the paper and complete all components of the message triangle.	Diagram of message triangle. A blank triangle for students.

Instructor does…	Students do…	Resources
Set up peer review / discussion of the message triangles (6).	Comment on their partner's message triangle (7).	
		15 min
Announce and explain assignment (8).	Turn the message triangle into communication piece.	Platform for sharing the assignment for peer-review.
		45 min
Monitor peer review (9).	Conduct peer-review and submit assignment.	
		30 min
Total duration in-class = 175 min out of which 105 minutes can be assigned as homework		

Notes

(1) We use an article written by Bressman et al. (2016) on the visual navigation and terrestrial locomotion of Mummichogs. Students find this paper engaging, and they can approach the story from many angles. Selecting an article that is engaging, entertaining, or controversial can be helpful for this exercise.

(2) A think-pair-share exercise helps every student participate. Students first need to think about their favourite story and then share it with their partner(s) before sharing with the whole class.

(3) The answer for audiences is never "everyone" or "the general public". Students need to realize that they cannot communicate with everyone on the planet. They need to narrow the audiences down. Often, they mention education level (high schoolers, college students, etc.), location (coastal cities, Australia, etc.), age groups (children, Gen X, etc.) or socioeconomic status. Within those broad categories, you can further note race/ethnicity, gender and sexual orientation, faith, language, cultural norms and worldviews held by these audiences. The goal is to identify how diverse audiences can be. Encourage them to probe further. For example, elected officials are an audience, but you can further refine it to elected officials who serve on your state's agricultural committees.

(4) Building a message triangle requires the following steps:

  i. Choose your audience
  ii. Establish your goal: what do you want your audience to think or do?
  iii. Identify the message: what do you want your audience to know?
  iv. List the main characters of your story.
  v. Develop key points: three strongest arguments for your message.
  vi. Use details: examples, analogies, visuals and stories that make your key points understandable.

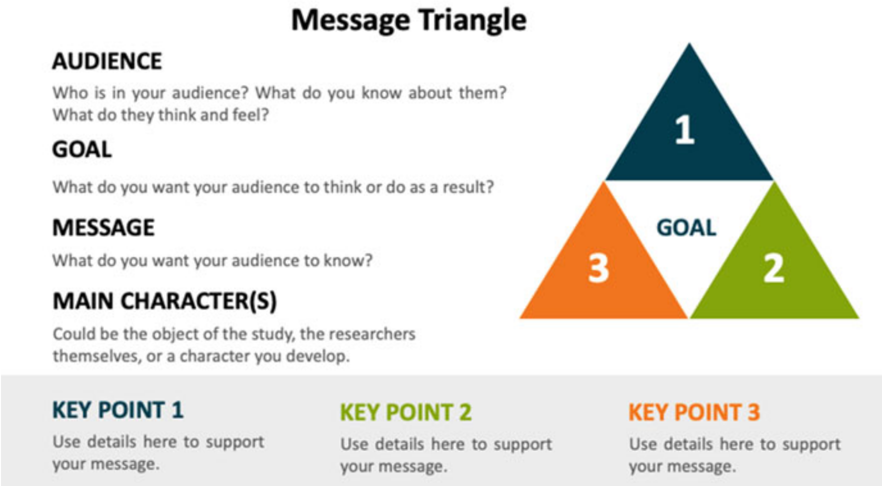

Fig. 41.1 Diagram of the message triangle

(5) The message triangle can be hand drawn, or the instructor should provide a blank triangle. This activity can be either a homework assignment or completed in class.
(6) We have done this as a whole class with volunteers sharing the message triangles, as a paired activity or in small breakout rooms online. The goal is for the students to see how many different ways one can structure a story from the same journal article.
(7) Students should use the triangle diagram (Fig. 41.1) to check if all elements of the triangle are present. They should identify whether the audience is realistic (small, properly identified), the goal is reachable, the message is clear, and the key points are understandable. Different students will choose different audiences, identify different key points, and define different goals, even if they are using the same paper for the message triangle. That should not be treated as an error.
(8) To tie the message triangle together with storytelling, it is important that students create a written or multimedia communication using the triangle. For example, we have asked students to turn the message triangle into a 300–500-word blog post-style story or create a Twitter thread of their story as an assignment. You can choose whatever communication form you like. We set up a peer review within the LMS, so students can give and get feedback on their work.
(9) Can be a homework assignment.

41.5 Top Tips for New Instructors

1. Use the same journal article for the entire class. It is essential for the students to have the “aha” moment when they see how many different ways a story can be told.

2. Help students differentiate scientific writing from writing for non-technical audiences. Remind the students constantly about their selected audience, as students will fall back into their comfort zone of technical writing.
3. Students may like a little more structure for organizing their three key points. Depending on the goal of their communication piece, it can take many forms. This can include assembling the information in the form of problem-solution-benefit, beginning-middle-end, value-scope-impact, etc.
4. Sharing the message triangle and the blog posts with each other is a key element of this exercise, so students understand the diversity of audiences and the diversity of angles for the same story.
5. We encourage students to start a public blog, add pictures or drawings to their stories and post them on their blog site.
6. Let the creativity of the students shine! We have seen students taking many approaches, from turning scientific journal articles into poems, children's books, graphic novels and personal letters.

Reference

Bressman, N. R., Farina, S. C., & Gibb, A. C. (2016). Look before you leap: Visual navigation and terrestrial locomotion of the intertidal killifish *Fundulus heteroclitus*. *Journal of Experimental Zoology Part A: Ecological Genetics and Physiology, 325*(1), 57–64. https://doi.org/10.1002/jez.1996

Website Links

How to create a thread on Twitter. https://help.twitter.com/en/using-twitter/create-a-thread. *Accessed 30 January 2021*.

Starting Your Podcast: A Guide for Students. https://www.npr.org/2018/11/15/662070097/starting-your-podcast-a-guide-for-students. *Accessed 30 January 2021*.

Science Blogging 101. https://www.theopennotebook.com/science-blogging-essential-guide/science-blogging-101/. *Accessed 30 January 2021*.

AAAS Communication Toolkit (Flipping the triangle). https://www.aaas.org/resources/communication-toolkit. *Accessed 30 January 2021*.

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One-Line Stories as Connections Between Slides

42

Alice Motion, Yaela Golumbic, Reyne Pullen, and Peter Rutledge

Storytelling - Organising - Writing

42.1 Learning Outcomes

Oral presentations are an important tool for communication and a ubiquitous feature of academia and the workplace. Most oral presentations use slide decks, and they often focus on slide *content* more than the narrative connection between the slides. This communication activity equips students with an approach that can transform their presentations.

By completing this exercise, the learner will develop (i) storytelling skills that enable them to share information in clear and compelling ways; (ii) techniques to better remember individual slide content by focusing on the links between slides; and (iii) transferable skills to structure meetings or important conversations.

42.2 Teaching Context

We have used this activity with PhD and senior undergraduate students prior to final research seminars or conference talks, with students preparing for science communication competitions and with colleagues preparing for public lectures.

Developing one-line stories is a particularly useful technique for those who are not presenting in their first language or who find presentations nerve-wracking, as

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this technique assists with remembering content and building confidence in storytelling.

This activity is useful for students at all stages but is particularly relevant for senior students who are preparing for significant research presentations. It is also a valuable way to prepare students for the workplace.

42.3 Overview of the Teaching Activity

This activity begins with small groups of students selecting (or being assigned) a science topic to communicate. Each group then collaborates to define their audience and purpose. In small groups, the students complete tasks that challenge them to consider the narrative structure of their communication, by focusing first on their communication as a story and then on the connecting phrases that will help their audience to follow the storyline.

Students choose a topic they want to present, then map out a draft presentation structure and create content-relevant titles for their slides. Students then write the connecting lines to be spoken at each slide transition, before finally building the content of the slides. Finally, students present a draft version of their presentation to the class and receive feedback before refining the slide content and script.

42.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Ahead of the session, assign students into groups (1) of three and ask each group to consider a topic they wish to present. Ask students to define the audience and purpose of their communication.	Choose their topic and gather resources to support their presentation.	 30 min
Explain the purpose and wider application of the exercise (2) but do not reveal all details of the session. Witholding detail challenges students to approach this task differently.		 5 min
Introduce the idea of telling stories using very few words (e.g. Haiku, Netflix series/episode summaries). Challenge students to think of different titles for their talk: ‘the Netflix title’, ‘the clickbait headline’ and the ‘most boring headline’. Then, ask them to converge on a compromise and make a title that is both engaging and informative (3).	Collaborate to think of different titles, then share them with the class, either as group discussion or via a class discussion board.	Examples of titles and other short stories. Appendix 1 20 min

Ask students to create a blank deck of four slides (a title slide plus three for content) and to write draft titles on each slide. The title of each slide should reflect the planned topic/content of the slide, even if written in a humourous way. Ask students to leave the slides otherwise blank. Then, ask students to write another line at the bottom of each slide which forms the connecting story script. Also ask students to write an opening and a closing line to their talk (4).	Work in groups to create a draft slide deck with content titles. Collaborate to write the script with opening, linking, and closing statements.	Appendix 2 30 min
Encourage students to work on the content of their slides outside of class and to draft a script for their 3-minute talk. Remind them to include the lines that link the slides.	Collaborate to produce a draft talk. Include the linker statements in the script.	 60 min
Facilitate student presentations of their talk to the class (or in smaller groups depending on class size (5)). Ask two students from the group to presenting the slide contents, while the third delivers the connecting lines for emphasis (3 min) The class provides feedback on the talk and connecting lines (6 min).	Present their work. Act as critical friends (6) for classmates to provide feedback.	 60 min
Invite students to work together outside of class to refine their slides and script based on in-class feedback before submitting their slides and script as a group assignment.	Collaborate to produce a final version of their talk and a script for submission.	 60 min
Total duration in-class = 120 min based on 2 x 1 hour classes with 2 hours of work outside of class (7).		

Notes

(1) This can be completed as an individual or group exercise. It is described here as a group activity in order to further develop student communication skills.

(2) The ability to give an engaging oral presentation supports students in their assignments and preparation for work. The content on each slide is important, but a logical and engaging narrative progression through this content can

transform the impact of a presentation. Importantly, students gain transferable skills as they consider the links between parts of an argument or slides in a presentation. Students will be able to use storytelling skills when convening a meeting, pitching an idea or structuring difficult conversations.

(3) An optional extension activity for homework or in-class is for students to watch example online talks (e.g. TED-style talks) and to make note of the linking lines used by the speaker to connect their slides. The choice of lines can be analysed in-class to provide students with further inspiration for their own talks.

(4) Emphasise the importance of the connecting lines here rather than the content and the way that the connections are essential in weaving together a talk with a strong narrative and a memorable start and finish.

(5) This activity requires approximately 10 minutes per group so it can be completed as a whole-class exercise or in subgroups with larger cohorts.

(6) You may want to coach students on how to provide and accept constructive feedback, as students can be quite harsh on each other and themselves!

(7) This activity can also be completed within research groups where students map out and practice conference talks or seminar presentations, with research group members providing feedback.

42.5 Top Tips for New Instructors

1. This activity works well when students present on a topic that they have prior knowledge of (e.g. in the discipline of science that they study or research).
2. If students are struggling with this approach, try starting them off with a well-known story from their past (e.g. a fairy tale or children's book). After they get the idea of the linker sentence, move them on to more abstract science stories.
3. When creating presentations, students (and professionals) often create the content first and only later think about the links between their slides. This exercise teaches students to begin by considering the flow of the presentation and to think about it as a story. Focusing on storytelling and making an analogy to familiar stories/books/movies will help students internalise and implement this method. Providing engaging, culturally relevant and appropriate resources make the initial tasks more effective and enjoyable for students. Similarly, providing good examples of talks within your chosen discipline area as extra resources will benefit students.
4. Perhaps try out this method on a talk that you are preparing yourself for a conference or a lecture for one of your classes, and share this experience with students as part of this exercise.

Website Links

Appendix 1: Worksheet 1: Short, Sharp Science Stories.
Appendix 2: Worksheet 2: One-Line Stories.
These Appendices are also available at SCOPE Group Resources for Teaching Science Students to Communicate: A Practical Guide, Accessed 22 July 2021.

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Creating a Personal Narrative: Storytelling for Scientists

43

Michael Winikoff

Storytelling - Engaging - Genre

43.1 Learning Outcomes

Humans tell stories. Storytelling helps us make sense of the world, process new information, build trust, and establish credibility. Stories can also be an effective tool for scientists as they interact with the public and colleagues. Sharing a passion for science through a personal narrative can help audiences relate to the storyteller as a person and pave the way for deeper conversations about science and its impact on society.

In this exercise, students will learn to identify events and experiences that helped shape their science identity and research interests; develop a compelling personal narrative; and perform or record their story for peers. Students will also learn to modify their personal narrative based on their audience and communication goals.

43.2 Teaching Context

This exercise works best in person but can be used online with breakout rooms. In both situations, students should be able to engage with one another and provide peer feedback. This exercise can be particularly helpful for early-career scientists, but the skills are valuable at any level. The 3-hour activity can be split into shorter sessions or expanded to include a 3-minute thesis-style performance or story competition.

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43.3 Overview of the Teaching Activity

In this eight-step process, students learn to understand and tell their personal narrative. At the end, students may choose to perform or record their narrative for their peers or another important audience. This exercise can be completed in one 3-hour session but can be broken up across several shorter sessions. Steps 1, 4, and 8 and the extension can also be assigned as homework.

43.4 Runsheet and Lesson Plan

Step 1: Explore storytelling as a way of sharing information and establishing trust
Instructor: Before class or as an in-class assignment, ask students to listen to and watch Resources 1 and 2. In the context of the two Resources, lead a short discussion, using the prompt in Note (1). Then, ask students to identify 3-5 contexts in which storytelling could help them as a scientist. Whiteboard the responses in each case. ***Students:*** Respond to the prompt. Then, in small groups or individually, brainstorm to identify contexts in which storytelling could help them as a scientist. Contribute these to the class discussion and whiteboard notes. ***Resources:*** Resources 1 and 2***;*** Computer or device to access video and podcast. Pencil or pen; whiteboard; 30 min
Step 2: Consider audiences students may wish to engage and profile a target
Instructor: Explain that, to communicate effectively, you need to know your audience, because audiences have different interests, knowledge bases, and belief systems. Ask students to identify different audiences they may encounter as scientists and whiteboard these with the group. Then, ask them to choose ONE target audience with whom they would really like to communicate, and write an audience profile. Ask students to write their profile answers on a notecard, label it "Audience", and keep it for later. ***Students:*** Consider different audiences and contribute to the class discussion. Individually, choose ONE audience, and use the notecard to write their profile. Consider questions like: How old are they? What's their educational background, gender, profession, or hobby? Do they have a sense of humour? What type of language is appropriate? What is your goal in communicating with this audience? ***Resources:*** Whiteboard to note class ideas. Pencil or pen; notecards; 20 min

Step 3: Identify pivotal experiences that shaped students' science identity.
Instructor: Explain to students that one way to connect with an audience is to share your origin story – the story that explains your passion for science and what sparked your interest. Explain that they are going to now start work on their personal narrative. Lead a brief discussion with the whole group, using these prompts: 1. Do you remember what first sparked your interest in science? 2. Did a childhood experience ignite a passion for science? 3. Did someone inspire or challenge you? 4. What emotions did you experience? 5. Was the incident funny, awe-inspiring, intimidating, sad? Ask students to use a different notecard for each event and label each card "Inspirational Experience." Ask students to consider their target audience and choose the experience that is most likely to connect with them. ***Students:*** Brainstorm to list three formative events or experiences that helped shape their journey as a scientist. Write them down, using a different notecard to list each experience. For each experience, explain what inspired them and how it changed their perspective on science. Then, choose the appropriate formative event for the target audience ***Resources:*** Pencil or pen; notecards; 20 min
Step 4: Learn to recognize the basics of story structure.
Instructor: Explain that there are many ways to think about stories and story structure, but all stories have a beginning, a middle, and an end. *Beginnings* **set the scene**, introducing us to the main character and their circumstances. In the *middle* of the story, the main character encounters a **transformative experience**, often in the form of a setback or challenge. At the *end* of the story, the main character returns to a **new normal**, equipped with new knowledge and experience. ***Students:*** Watch Resource 3 and practice identifying elements of the story by answering the following prompts:

1) In one sentence, describe the main character and the setting at the beginning of the story.
2) List three details the storyteller uses to set the scene.
3) What challenge did the main character face?
4) How were they transformed by the experience?
5) What does this character's new normal look like?

Resources: Resource 3; pencil or pen; notecards; 30 min

Step 5: Identify details, images, or metaphors that set the scene and introduce the student as the main character in their own narrative (the beginning).

Instructor: Help students find the beginning of their personal story. Remind them that details make a story come alive, and that Bill Stanley originally told his story in a lecture hall, without the benefit of animation. He was a scientist but also a gifted storyteller who used carefully chosen details to bring his story to life.

Ask students to identify details from *The Switch* that helped make the story engaging. Discuss ways in which location, setting, and small details can reveal important information about a character (3).

In preparation for the student activity, ask students to reflect on the experience they identified in Step 4 and imagine themselves as the story's main character. This helps them begin to set the scene for themselves as the main character of their story.

Students: Consider the event or experience they described in Step 4 and answer the following questions on a notecard. Each answer should be 1-2 sentences.

1. How did the event begin?
2. Where were you?
3. Describe yourself (the main character) at the beginning of the story.
4. List three details you can use to set the scene.

5. What do these details reveal about you and your circumstances at the beginning of the story?

Write responses on a notecard(s) labelled "Setting the Scene."

Resources: Pencil or pen; notecards; 20 min

Step 6: Describe a challenge or obstacle that transformed the student's understanding of themselves and their circumstance (the middle).

Instructor: Help students find the middle, or the moment of transformation, in their personal story. Using Resource 3 (*The Switch)* or student examples, ask students to reflect on the moment when things began to change.

Offer examples of obstacles or challenges one might face. These could be a setback in achieving a goal; a seemingly insurmountable obstacle (physical or emotional); an anomaly; or an embarrassing moment.

Students: Answer the following questions on a notecard:

1. What challenge, obstacle, or setback did you face?
2. What surprising, funny, or shocking things happened?
3. What emotions did you feel at that moment?

Label the notecards "Transformation."

Resources: Pencil or pen; notecards; 20 min

Step 7: Describe how the experience changed the storyteller.

Instructor: Help your students find the ending, or the new normal, of their story. When an audience listens to a story, they follow the main character (you) on a journey. They will want to know how you overcame your challenge and what you learned along the way.

At the end of the story, life returns to a **new normal**, but the audience will want to know how the experience changed you.

Discuss ways in which metaphor, references to events from the beginning of the story (callbacks), or changes in surroundings can bring the main character to life, reveal their new insight, and draw the audience deeper into the story. For example:

1. It felt like I was flying above it all…
2. The fog lifted…
3. It wasn't a new species unknown by science, but…
4. I hobbled away with a new mission…

Students: Answer these questions on a notecard. 1. How was the challenge resolved? 2. What feelings did you have at that moment? 3. What details do you remember? Was there a change in the physical environment? Your mental or emotional state? 4. What did you learn as a result? 5. How will you carry this knowledge with you as life returns to a **new normal**? Label this notecard "New Normal." ***Resources:*** Pencil or pen; notecards; 20 min	
Step 8: Organize events from the brainstorming sessions above and draft a personal narrative to share with classmates.	
Instructor: Help students craft their personal narrative, using all the elements they have just built in Steps 1-7. Ask the students to spend 20 minutes pulling the pieces of their story together. If this seems daunting (or if their target audience no longer seems appropriate), ask them to imagine telling the story to a group of close friends. Let them know it's okay to exaggerate for effect, as long as they don't tell a complete lie! The important thing is to write something and try it out in front of an audience. ***Students:*** Gather the notecards and notice how the elements create an outline for their story. Construct a narrative, using these notes for reference. Their story should set the scene, describe the journey they took, and reveal what changed as a result. Keep the target audience in mind during writing. ***Resources:*** Pencil or pen; notecards or notepad; students may also compose their narrative on a computer; 20 min	
Extension: Performance and revision	
Performing or recording stories for their peers helps students gauge audience response, incorporate feedback, and polish their storytelling skills. As an extension, give students the opportunity to perform the story for the class, provide feedback to each other, and potentially revise their story. You can encourage students to provide feedback to their peers using one or more of the following prompts: 1. What details brought this story alive for you? 2. Were you able to identify the transformative moment? Were you convinced by it?	

3. How did the "middle" obstacle shape the storyteller's interest in science? 4. What was the predominant emotion conveyed through the story? 5. Give the storyteller one suggestion for improving their story. ***Resources:*** Around 60 min - depending on class size and sharing format (4).
Total duration in-class = *180 min + 60 min extension*

Notes

(1) Prompt: "Stories are a mechanism that human beings evolved to help us package information about who we are, how we survive, what we care about and then spread those ideas through time and space." Liz Neeley Former Executive Director of The Story Collider, from Your Brain on Storytelling (Resource 1).

(2) Ask students to label their notecards with the title of each step for easy reference (Audience, Beginnings, Middle, End). Color-coded notecards can also be used, if available.

(3) Tips for scene-setting details include:
1. Sensory experiences (colors, sounds, smells, temperature)
2. Feelings (confusion, wonder, curiosity, fear)
3. Location and circumstance

(4) Not every student has to perform a story for the group to benefit. Stories can also be shared in small groups or recorded later if there are time constraints.

43.5 Top Tips for New Instructors

1. With a new group, I often ask each person to introduce themselves and tell us one thing that isn't evident by looking at them and that leaves us wishing we knew more. I use this exercise to introduce the idea that good stories are about the potential for discovery.
2. Learning to tell a good story takes time and practice. Good storytellers test their material on a variety of audiences and let the story evolve over time. This exercise provides one framework and lens for storytelling. Encourage students to take risks and have fun. No one will become an expert storyteller after one exercise. If you are grading this assignment, consider creating a rubric that rewards risk-taking and experimentation.
3. Consider supplementing this exercise with Amanda Niehaus' chapter, *A practical guide to storytelling frameworks* [Editor to insert link or page #]. This chapter uses Randy Olsen's ABT format, which can help students transition from freeform storytelling to structured narratives. It also helps students stay focused on the story arc and narrative thread as their stories evolve and become more complicated.

4. Once students have experience developing a personal narrative, consider moving onto storytelling related to professional goals. If the first personal narrative explores the student's origin story (what inspired me to become a scientist), encourage them to try other narratives that explore science identity (what I study and why you should care, too) or a professional quest (a research journey explaining a particular finding or line of investigation). Each narrative might be appropriate for a different audience and can often be incorporated into professional talks, engagement activities, or casual conversations.

Resources

Resource 1: Your Brain on Storytelling.
(https://www.npr.org/2020/01/13/795977814/your-brain-on-storytelling). *Accessed 21 Jan 2022*.

Resource 2: Paul Zak — Empathy, Neurochemistry and the Dramatic Arc.
(https://futureofstorytelling.org/video/paul-zak-empathy-neurochemistry-and-the-dramatic-arc). *Accessed 21 Jan 2022*.

Resource 3: The Switch: A Bill Stanley Story.
(https://www.youtube.com/watch?v=HwaaH6ILs40). *Accessed 21 Jan 2022*.

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Using Art and Reflection to Guide a Deep Dive into Science

44

Elsa Cousins

Storytelling - Intent - Distilling

44.1 Learning Outcomes

Guiding students through creative explorations of science and communication can help them reach a deeper understanding of science and their own relationship with it. There are two main learning outcomes for this activity: (1) students will explore how scientific information can be conveyed using visual art, and (2) students will generate personal reflections on specific topics in science using creative communication methods.

By building creative expression into the learning process, students can explore their interests and develop a more personal connection with science and communication. As a side effect of providing creative responses (where there is no "right" answer), students become more comfortable with ambiguity and uncertainty.

44.2 Teaching Context

Creative expression is linked to higher-level intellectual engagement and can help students understand their personal relationship with learning. This activity works well as part of courses that are heavy on discussion, providing students a place to reflect outside of class. I typically provide a reflection prompt based on the current class topic and give students a week to complete their reflections post-discussion.

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This activity can be done once or repeatedly throughout a course and works across disciplines. By tailoring reflection prompts to your specific course, this assignment guides self-reflection and helps students identify and dive into their own interests.

44.3 Overview of the Teaching Activity

This activity is can be broadly described as a "field reflection journal." The instructor introduces the concept of a scientific field journal during one class period. A short overview of field journals (or lab notebooks or other reflective writing tools) connects students to the history of science writing and visuals as personal tools for learning. Students are then shown examples of art/science connections and encouraged through a series of reflection questions to explore them in small groups. After this introduction activity, students are given a prompt to respond to outside of class. Students may produce a range of reflective responses depending on instructor input—for example, they could be asked to produce poetry, short videos, multimedia works, etc. Prompts that ask students to branch outside of simple written responses can be particularly helpful for pushing students to reflect on their personal creativity and connection to science.

Creative communication helps students build their own sense of science identity and develop a broader understanding of how others may approach similar issues in different ways. Through this assignment, students develop their communication skills from synthesizing information into different forms and making connections across topics, themes, and mediums. In the extended version of this activity, students engage with a variety of instructor-generated prompts throughout the semester.

44.4 Runsheet Lesson Plan

The reflective nature of this activity means it is primarily done by students outside of class time. This activity is described below in three stages. Students often excel when given the opportunity to pursue creative field journal entries weekly, as described in the extension to the activity.

Instructor does…	Students do…	Resources
Before class		
Generate a reflection prompt based on class topics (1). Find an example of science communication art (2).		Example prompts Example art 10-20 min
In class		
Provide overview or short lecture describing field journals (3).	Listen	Exemplar field journals (4) 10 min
Share a few examples of art/science collaborations relevant to your class's topic	Note what stands out, what makes a piece "effective" for them (5).	See (1) and (2) 10 min
Provide example reflection prompts and responses (6). Ask students what art mediums they would use to communicate a scientific concept.	Pick a prompt and work in small groups to research an art/science combination. Groups generate a single PowerPoint slide to explain their choice to the class (7)	Example prompts and responses (6) Internet access Computers 20 min
Invite students to present ideas (optional, depending on size of class)	Each group shares their chosen prompt and the art/science combo that they chose in a two- to three-minute presentation	Projection capacity for student slides Varies
After class		
Provide the reflection prompt	Respond to prompt in their field journals (8).	Field journals 10 min

Extension 1 *Instructor* asks students how they felt about the assignment and facilitates small group discussions (9). *Students* share and discuss responses in small groups.	 20 min
Extension 2 *Instructor* generates reflection prompts based on class topics for multiple weeks. *Students* respond to prompts throughout the semester (10).	See (2) for keywords Varies
Total duration in-class = 50 min [+ optional student presentations, + 20 minutes for extension activity in next class period]. Activity can be extended throughout the semester by providing additional reflection prompts weekly	

Notes

(1) Example prompts vary based on subject and the instructor's goal. For example, an ecology class could incorporate environmental art installations, an animal behavior class may explore art inspired by different animal sensory systems, and data science classes could discuss the art of well-made scientific figures. Here are some starter ideas and exemplars:

(i) After a class period on microplastics in the ocean, students are assigned to explore environmental art installations that repurpose plastic waste and create their own interpretation of this using objects from their home—see Washed Ashore.

(ii) After a class period on endangered species, students view an art installation related to climate change and species decline. They are asked to choose a species and imagine its evolutionary trajectory in the next geological age—see Hemlock Hospice.

(iii) After a class period on microbiology, students view microscope art and are asked to submit a photograph of something viewed up close and consider how that view changes the object—see Microscopic Tears.

(2) Keywords for finding relevant art: installation, science communication, field journal art, science art, contemporary art. For videos of artists speaking about their work, try the Methods of Art Archive of Artists Interviews website.

(3) The goal is to emphasize creativity and freedom of exploration. Try connecting to historical figures in science (e.g., Charles Darwin, Leonardo da Vinci) and contemporaries who straddle the line between art and science. Mixing people that students may be familiar with (e.g., Brian May, lead guitarist in Queen and

astrophysicist) alongside examples of individuals using art as communication (e.g., Kathy Jetñil-Kijiner and Aka Niviâna, connecting poetry and climate change) can provide students with context for why they are doing this assignment.

(4) Exemplar field journals are available at The Sketchbook Project Digital Library and the American Museum of Natural History's Keeping a Field Journal site (see Website Links).

(5) Things that may be effective for students include art that spurs more questions than answers, art that stirs an emotional response, or art that explains a complicated concept.

(6) Examples from my own students include responding to a prompt about human/geological interactions with a series of their vacation photos and a brief written analysis of the geological forms in the background. Another student researched how humans modify shorelines and illustrated an imaginary city incorporating these methods for combatting sea level rise. For each example prompt listed under (1), I have had students submit:

  (i) Microplastics—a PowerPoint tracking the journey of a plastic water bottle they purchased from a dining hall and from a petroleum manufacturer to a landfill or the ocean
  (ii) Endangered species—a short audio recording of the future of Louisiana swamps where they have been overtaken by nutria, a giant invasive water rat, narrated in the style of David Attenborough
  (iii) Microbiology—a series of close-up images of vegetables and a written reflection on how images lose context with increasing scale

(7) The medium of response is flexible, but limiting students to 20 minutes of class time and a single PowerPoint slide forces them to work together quickly, choose something they find interesting and relevant, and figure out how to explain the connection to their peers. This is an exercise in discovering relationships across disciplines.

(8) One week is generally sufficient time for students to develop a response.

(9) Asking students what they found most challenging encourages honest discussion. Establishing a personal connection to creative communication can be key to discovering their own interests and understanding how others may have different perspectives on similar subjects. Methods for evaluating creative student work are often results-oriented, rather than encouraging students to focus on the process of creative engagement itself.

(10) Extended reflection can be a tool for documenting academic growth for individual students, helping them frame their thoughts and progression over time. This can lead to making connections among class topics and individual interests while building stronger communication skills.

44.5 Top Tips for New Instructors

1. Remember that communicating through the creative process requires mindfulness and a personal investment in subject matter. Emphasis on an inclusive and welcoming learning environment is key to student development when bringing creativity to the classroom. Support students around the idea that there is no "right" answer for their creative work—they may have some anxiety about this unknown.
2. Each reflection assignment comes with a prompt to link the class topic to art, to promote students' creativity, and to encourage their further investment in the class topic. This approach is highly adaptable. The number and type of prompts are really only limited by your imagination and the ideas you want your students to explore.
3. Depending on student experience level, providing more guidance in the prompts can help jump-start the creative process and build confidence. By specifying media and format, you can build elements of forced creativity into reflection prompts, and students will experiment with communicating in formats they may not otherwise have engaged with.
4. Students can struggle to make a creative reflection response without initial guidance as to what that may be. In the early weeks of the field journal, provide prompts with more structure. An early prompt might say, "Find or generate an image that connects to this week's topic, and write a caption that explains why you chose it." This leads students to pair a visual with written text and fits well with a discussion about figures in scientific papers. Later, prompts may be broader. For example, after a discussion of climate change and global capitalism informing the funding of science, students experienced with reflection can address an open-ended prompt like, "Imagine how our discussions may be reflected in a future impacted by climate change." Transitioning from clearly defined expectations to more open-ended reflections may be difficult for some students, but think of it as removing the training wheels of a bicycle—the guided process helps build stronger creative confidence and communication skills moving forward.
5. Provide positive feedback to foster student creativity. Pushing students out of their comfort zones to try different ways of responding can be difficult, but it ultimately leads to new understandings of the subject matter.
6. Try highlighting particularly insightful responses in class, to show students that their work is being seen and appreciated. Other students can also benefit from seeing the work their peers are doing and be inspired to try similar things themselves.

Website Links

A collection of traveling art installations and education resources, Washed Ashore. (https://washedashore.org/). *Accessed 10 Jan 2021*.

An example of installation art concerning climate change and endangered species, Hemlock Hospice (Art installation at Harvard Forest in the US). (https://harvardforest.fas.harvard.edu/hemlock-hospice). *Accessed 10 Jan 2021.*

An article on microscopic artwork featuring Microscopic Tears. (https://www.smithsonianmag.com/science-nature/the-microscopic-structures-of-dried-human-tears-180947766/). *Accessed 10 Jan 2021.*

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An Archive of Artists Interviews, Methods of Art for finding relevant artists and work. (http://methodsofart.net/). *Accessed 10 Jan 2021.*

The Sketchbook Project, a digital library of artist sketchbooks. (https://www.sketchbookproject.com/). *Accessed 10 Jan 2021.*

Tips on Keeping a Field Journal (The American Museum of Natural History Biodiversity Counts Curriculum Collection). (https://www.amnh.org/learn-teach/curriculum-collections/biodiversity-counts/what-is-biodiversity/keeping-a-field-journal-1-eleanor-sterling). *Accessed 10 Jan 2021.*

A short poetry film on climate change, Rise: From One Island to Another (Kathy Jetñil-Kijiner and Aka Niviâna). (https://350.org/rise-from-one-island-to-another/). *Accessed 10 Jan 2021.*

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Part IX

Practice Communicating with Intent

So What? Writing an Impact Statement

45

Narelle Hunter

Intent - Genre - Writing

45.1 Learning Outcomes

After completing this exercise, the learner will be able to convey the impact of their research clearly and concisely to a wider audience. Learners will be able to determine the appropriate language to use when communicating by considering the purpose of the communication event. They will also develop an understanding of what it means to communicate research outcomes with intent.

45.2 Teaching Context

This exercise was developed in a first-year undergraduate core biology unit to help students learn how to communicate the outcomes of a major research project. In the unit, students completed research projects in small groups—they designed the research, gathered their own data and interpreted the results. However, many of the students struggled to communicate their projects to others (outside of their scientific peers). The exercise was developed in response to this problem.

A crucial aspect of undergraduate science education is learning how to communicate with non-scientific audiences, yet many students express concern about having to "dumb down" the scientific content for a lay audience. When students say, "dumb down", they mean they can no longer use the specialist language they

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would employ in expert-to-expert communication. They struggle to use terminology that renders the ideas accessible to a lay audience; they may even feel that making science accessible equates with reducing its value.

This activity helps students understand that explaining the value of science is the key to making it accessible. In this exercise they learn to explain, in simple terms, why an aspect of science is important and how to present research in a way that helps their audience care and engage with it. This activity helps students to identify the "so what?" of research and engage more effectively with a non-scientific audience.

45.3 Overview of the Teaching Activity

This activity provides opportunities for students to engage with genuine examples of impact statements written by scholars within their discipline, demonstrating the importance and significance of this type of task to the real world and future employment. The activity is best linked to an authentic research project in which the students carry out laboratory- or field-based projects and report on the results, but it can also be done using existing research as a stimulus.

Impact statements have a variety of purposes, including seeking funding and engagement with a wider audience. Sources of scientific funding are often government ministers or private industry, many of whom are not familiar with the technical jargon that scientists commonly use. Students learning to communicate outside of their peers find it challenging to drop the jargon for more accessible language for two reasons. Firstly, they are being assessed by a scientist and must demonstrate understanding of technical language in most assessment tasks and secondly because using this language is equated with more complex ideas. However, this activity highlights that the key to engaging with more diverse audiences is to use language that is accessible.

To ensure that learners experience engaging and discipline-relevant learning, the activity is based on three approaches to writing. Each acts as a lens to understand the learning goals of the activity. (i) A product-based approach supports students to develop writing proficiency through imitation, modelling vocabulary and syntax on discipline-specific examples (Badger & White, 2000). Providing examples of writing for a non-scientist audience shows that "dumbing down" is not devaluing science, rather making it more accessible and valuable. (ii) Process-based formation of texts is important, emphasising the importance of drafting and revision and the recursive nature of the writing process (Nordin, 2017). This can be facilitated by students reviewing drafts of each other's work and discussing the value of drafting to the final product. (iii) The importance of genre as attention is placed on the social context in which writing is produced and the ways in which language functions in social contexts (Hyland, 2003). Possibly the most challenging of aspects to address, students who are completing the task for assessment must demonstrate understanding of scientific content while incorporating language suited to a broader audience.

45.4 Runsheet and Lesson Plan

This lesson plan is designed to be flexible for the needs of students. It can be run in class individually or in small groups or as a homework activity. The activity is not designed as an assessment task alone but is useful if associated with an assessable piece of work and exemplars are provided.

Instructor does…	**Students do…**	**Resources**
Facilitate discussion of the question: *"Who is research for and how do they access it?"* (1)	Discuss with instructor and peers.	 20 min
Provide exemplar impact statements (3).	Select exemplar impact statements and read (2).	Exemplar impact statements 10 min
Facilitate discussion of the question: *"What is research impact?"*	Discuss and define (4).	 20 min
Discuss the purpose and style of a scientific impact statement (5).	Discuss with peers.	 20 min
Facilitate discussion of components of the impact statement (6). Record student responses	Discuss and share with peers the components of the impact statements they have read.	Device to record responses (e.g., Whiteboard) (7) 20 min

Extension (20 min scaffolded - 60 min student-led) *Instructor* Facilitate discussion with students to identify each component of the impact statement from a research project (8). *Students* Draft one sentence for each impact statement section. In student-led approach review another student's draft and provide feedback. *Extension (1-2 weeks)* *Instructor* Assign an Impact Statement writing task for assessment (Appendix 1 and 2). *Students* Write and submit an impact statement for assessment.
Total duration in-class = 90 min + 20-60 min extension activity + assessment

Notes

(1) Begin with discussion around where research funding comes from. Ask students to consider the importance of making scientific information available to all. Ideally research benefits everyone and should be accessible to all, so that they can make informed decisions. Students often make this conclusion during informal class conversations. Ask the students to explain how they would write about their research for a variety of different groups, such as primary school students, high school teachers or lawmakers—this provides an opportunity to discuss how science benefits from including a variety of voices and experiences and the role of language in accessing scientific information. If students use the term "dumb down", ask them to explain what they mean, and discuss how science might benefit from a range of literacies.

(2) Students can do this individually or in pairs. Reading can take place outside of dedicated class time. Exemplars allow imitation and a product-based approach.

(3) Exemplar impact statements should be provided from a variety of sources to ensure that students have a range of options available that align with their field of study. Exemplars should include examples written by researchers who the students know, as well as broader national and international examples. Impact statements are often found within research grant applications, and successful projects may be listed on your local government and/or funding body websites. Be sure to select examples that use accessible language (what students might consider "dumbed down") as this can be used to prompt discussion in class.

(4) Depending on the context of the assessable component, this can be open-ended (for students to define themselves) or more guided (where the instructor recommends specific resources). Examples of research impact definitions are

often provided by funding bodies. These can be used to demonstrate the real-world applications of the activity. The definition I use is from the Australian Research Council and describes research impact as "the contribution that research makes to the economy, society, environment or culture, beyond the contribution to academic research" (ARC, 2019).

(5) Key points to discuss: (i) What is the purpose of an impact statement? (ii) Who is the intended audience? (iii) What is and isn't included? (iv) What kind of language is used in the impact statement exemplars? (vi) How does the language differ from another scientific genre (e.g. a paper abstract). It is important for students to recognise that language should be clear, concise and formal while avoiding scientific jargon that may confuse the reader. One way to approach this is to select an example of an expert in another field (e.g. a law professor) and ask students to consider the language they would use to communicate scientific ideas to this person. Could a lawyer without any scientific background read and understand the text?

(6) A typical impact statement will include the following five components: (i) clear description of the issue or problem the research addresses, (ii) statement of action taken to resolve the problem, (iii) explanation of the impact, (iv) people involved in the research and (v) author's details and brief description of background and involvement in the research. Variation is common with only some parts included depending on the area of research and the purpose of the impact statement. Exploring aspects of the genre demonstrates the social context and the disciplinary differences that can affect the way things are presented. See Appendix 45.1 for an Impact Statement writing assessment task description that details the elements. Appendix 45.2 contains a marking rubric for this task.

(7) It is crucial that students have an opportunity to record the class responses, which will likely provide more variety in terminology than they can come up with alone. The discussion should be recorded in some way for the whole class to access, either in text or audio format, as this may be useful when they come to complete the associated assessment.

(8) This activity can be highly scaffolded by the instructor using a single example with the entire class or student-led using individualised projects. For individual assignments, sharing of writing and peer feedback is useful for writing development and to demonstrate the recursive nature of the writing process (i.e. we rarely end up with a perfect sentence the first time, and drafting vastly improves writing). If the instructor has concerns regarding possible opportunities for plagiarism, then an example research project could be used by the whole class to construct a practice impact statement, and groups provide feedback to peers. If highly scaffolded and completed with the class, identifying and drafting a single sentence for each section takes approximately 20 min to complete the draft impact statement. If student-led, working on individual projects each student will produce a draft in 20–30 min and spend 20 min reviewing each other's work and a further 10 min discussing the feedback with the author.

45.5 Top Tips for New Instructors

1. This activity can be challenging for many students as the style of writing is very different from scientific journal articles that form the bulk of their recommended reading (and writing). Discuss this challenge openly with your students, and remind them that feelings of discomfort in writing are normal and indicate that they are developing a new skill.
2. While not essential, it is helpful for faculty members to share their own impact statements. By reading their own professors work, students gain insight into the broader aspects of performing research. Personalising examples provides students with a genuine connection to the research and increases their engagement with the activity. You may be surprised at how willing your colleagues are to share their writing!
3. Early years students often struggle to identify their own relevant background and involvement in the research for this activity. It is important to highlight that any assessment takes this into account. If they are first-year students, then relevant background may include being enrolled in the current unit in which the activity is offered. Encourage students to think about the broader skills they bring to a research project in terms of organisation, planning etc. and how this differs from their group members if they are working in a team.

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Hyland, K. (2003). Genre-based pedagogies: A social response to process. *Journal of Second Language Writing, 12*(1), 17–29. https://doi.org/10.1016/S1060-3743(02)00124-8

Nordin, S. M. (2017). The best of two approaches: Process/genre-based approach to teaching writing. *The English Teacher*, 11.

Website Link

Australian Research Council Impact Studies. (https://dataportal.arc.gov.au/EI/Web/impact/ImpactStudies). *Accessed 27 Jan 2021*.

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The Communicate with Intent Framework

46

Chantal Barriault and Michelle Reid

Intent - Distilling - Engaging

46.1 Learning Outcomes

Students and scientists alike often find it challenging to adapt their communication style to different audiences. Our Communicate with Intent Framework is a tool that helps learners recognize the need to tailor communications according to different audiences in order to be effective communicators. The exercise in this chapter is a case study based on one particular scientific study and demonstrates how to effectively communicate science using the Communicate with Intent Framework.

After this exercise, students will be able to articulate the goal of their communication, identify the needs and values of different audiences, define their communication objectives, craft an essential message, and consider the appropriate modes of engagement for different audiences using a publication on conservation biology as a case study. Once a learner has completed the steps in this exercise, they will be able to plan purposeful and intentional science communication tailored to their audience.

46.2 Teaching Context

We have used this exercise in teaching science communication skills to upper-year undergraduate students, graduate students, university science faculty, and scientists of all disciplines. It is a valuable exercise that helps participants shift from presenter-

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centred to audience-focused communication. Students can visualize and easily develop a more strategic approach to different communication scenarios, including posters, government briefing notes, press releases, or academic presentations. Successful both as a face-to-face exercise and as a virtual online activity, the exercise can take one to two hours depending on the level of interactivity and group work.

46.3 Overview of the Teaching Activity

This activity demonstrates how, and provides a tool, to prepare for communicating science to different audiences. Many of the chapters in this book are building blocks to the Communicate with Intent Framework (Fig. 46.1), making it a good introductory or culminating activity for the classroom.

Before the lesson, students read a provided peer-reviewed science article on conservation biology. This article serves as a case study to demonstrate how to use the Communicate with Intent Framework as a tool for communication planning.

To start the lesson, introduce the students to the Framework, the content, and the relevance of each section, contextualizing the use of the Framework as a communications planning tool. Spend some time discussing the difference between an overall communication goal and the more specific nature of a communication objective.

Overall Communication Goal:					
Audience *Who do you talk to in the pursuit of the goal?*	Audience Values & Priorities *What do they care about?*	Inform Objective *What do you want them to learn or acknowledge?*	Action Objective *What do we want them to do?*	Essential Message *What is - the take home message?*	Mode of Engagement *What is the medium through which the message will be communicated?*

Fig. 46.1 The Communicate with Intent Framework. Additional rows can be added at the bottom of the table if the communication activity addresses more than one audience

Reflecting on the journal article, ask students to consider the Overall Communication Goal section of the Framework before walking them through the audience scenarios provided as examples.

Prompted by the examples, students consider how to engage with new audiences assigned by you or chosen by them. Individually or in groups, in class, or as homework, students fill the boxes of the Communicate with Intent Framework. Debrief with the group by asking students to share the challenges of specifying communication approaches for unique audiences. Complete the lesson by highlighting how the tool can be used in academia and in the workplace. Extend the discussion by reviewing how media outlets covered the research in the journal article.

46.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Assign the science peer-reviewed article (Resource 1) as reading before the next class. Ask students to identify the main findings of the study, and to consider what the authors might want to achieve when communicating about their research (1,2). Engage the students in a discussion about the difference between Communication Goal and Communication Objective (3).	Read article Be prepared to discuss why the authors would communicate their research, and to whom. *Extension* Students view Resource 2 before or after class.	Resource 1 Resource 2 35 min (1 h 40 min if including extension video)
Contextualize the exercise with respect to future employment or occasions where students may communicate science to various audiences (5).	Provide ideas on the types of audiences they may need to reach in a work environment.	5 min

Provide students with an empty Communicate with Intent Framework. Introduce framework sections, starting with Overall Communication Goal, and working through each column's meaning and relevance to communication planning. (6) Prompt students to offer possible Overall Communication Goals for Baxter-Gilbert et al. (2015).	Clarify understanding of the Framework. Generate ideas for Overall Communication Goal.	Resource 3 20 min
Select one or two example Communication Scenarios for target Audiences. Work through the given examples, moving left to right by row, to demonstrate how this tool generates a plan for effective communication (7).	Provide input and ideas to help fill the Framework.	Resource 3 Resource 4 15 min
Ask students to identify an audience of their choice for the Resource 1 paper, and work through each column for that audience (8).	Complete one or more rows for an audience.	25 min
Ask one or two groups to share an Audience row. Debrief with students by discussing what they found challenging and how they can apply this in a work environment (9).	Reflect and generate ideas.	15 min
Extension Students review media coverage of Baxter-Gilbert et al.'s (2015) article to demonstrate essential messages highlighted by the media (10). - Read or listen to media coverage. - Identify the key messages as reported by the media. - Reflect on how the media's messages align with the essential messages you identified in the Framework. Resource set 5 *Extension* Students consider how this Framework could be applied to a workplace scenario, group work in their study environment, or to the process of applying for a job.		
Total duration = 30 min pre-class + 80 min in-class activity + extensions		

Notes

(1) The Instructor can choose to assign the article to be read before class. The article takes most students approximately 30–40 min to read. To optimize reading and comprehension of the article, ask students to read the Abstract, the Introduction, the opening paragraph of the Methods, and the Discussion and Conclusion. A quick scan of the Results section will suffice for the purposes of this activity.

(2) This activity can be adapted for a different peer-reviewed scientific article that is more relevant to your field of science instruction or expertise. If choosing a different article for this exercise, keep in mind that, in our experience, students find it easier to complete the Framework when the article has clear implications for a variety of stakeholders. The exercise is also a valuable activity for a more fundamental or theoretical journal article that does not explicitly discuss applications or implications of public interest. Lastly, upper-year or graduate students could choose their own science topic or article for this exercise.

(3) A communication goal can be described as the long-term, desired, ultimate outcome of a communication plan or campaign (Besley et al., 2016). Examples include informing or affecting policy; influencing or changing individual behaviours; and preventing the extinction of a species. Communication objectives are shorter-term, more specific intermediate effects that help us achieve the broader communication goal (Besley et al., 2016). Examples include building trust with politicians and policymakers; framing issues to be relevant; and fostering excitement and engagement for an issue.

(4) The goal here is to show students that scientists (and themselves in future employment) must engage with different audiences in pursuit of their communication goals and that tailored approaches are needed for each unique audience. Examples of communication they may engage in include briefing notes (governments), press releases (editors), media interviews (public audiences), or internal communications (colleagues). The Communicate with Intent Framework is a tool they can use to help plan effective communication strategies.

(5) First, introduce an empty Framework to encourage students to generate ideas for the Overall Communication Goal. Introduce each column, and describe its relevance when planning to communicate. For in-depth content or further exploration of these column themes, see additional relevant chapters.

(6) We have provided nine completed Target Audience Scenarios in the Instructor's Examples. Use as many or as few of the examples you need to demonstrate the use of the Framework as a tool to plan communications. Working through different Target Audiences will highlight the need for different Objectives, Essential Message, and Mode of Engagement for each unique audience.

(7) This activity can be assigned as a collective group project, or smaller groups, each with unique audiences. Supporting prompts for this activity, if needed, can be pulled from the provided scenarios.

(8) The starting point of every communication effort begins with a communication goal, naming the specific audiences you will communicate with, and identifying what each of those audiences needs from you as the communicator. It is the only way you will accomplish the goal you set out to reach. Lead students to

recognize that for each person or audience that they will communicate with, they should go through this exercise at least mentally, but preferably on paper/document, to ensure impactful, targeted, and strategic communications.

(9) If the students are struggling to identify essential messages, they could be asked to listen/read media coverage before working through the rows of Audiences in the Framework.

46.5 Top Tips for New Instructors

1. Most students have only ever presented to, or communicated with, one or two audiences by this point in their academic career. These audiences are typically academic and/or technical specialists. The Communicate with Intent activity helps them realize that there is a spectrum of audiences. It also forces students to acknowledge that they can't use the same communication approach with every group that they work with or communicate to.
2. Students tend to struggle with identifying the values and needs of different audiences. Prompting questions that help include (in addition to asking "What do they care about?"):
   - What do you think matters to this group? Consider their personal and professional lives.
   - What do people in this group need to do well or to succeed in their job?
   - Do they have a vested interest in what others think of them?
   - Does this group of people have a financial stake in this research?

References

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Besley, J. C., Dudo, A. D., Yuan, S., & Ghannam, N. A. (2016). Qualitative interviews with science communication trainers about communication objectives and goals. *Science Communication, 38*(3), 356–381.

Resources and Website Links

Case Study Journal Article: Mitigating Reptile Road Mortality: Fence Failures Compromise Ecopassage Effectiveness, (https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0120537), *Accessed April 28, 2021*.

Making Science Communication More Strategic, Alan Alda Center for Communicating Science. Webinar by John Besley and Anthony Dudo (2019), (https://www.youtube.com/watch?v=C5fqUJcswJQ), *Accessed April 26, 2021*.

Blank Communicate with Intent Framework (Appendix 46.1).

Supplemental material for Instructors to use as examples and discussion prompts: Instructor Examples—Communication Scenarios for Target Audiences (Appendix 46.2).

Resource set of media coverage for Baxter-Gilbert et al. (2015) for use in extension activity.
Roadkill study shows more reptiles killed by fence designed to help. (https://www.cbc.ca/news/canada/sudbury/roadkill-study-shows-more-reptiles-killed-by-fence-designed-to-help-1.3019393). *Accessed January 28, 2021*.
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47 The Values Affirmation Exercise

Natalia Caporale and Brittany N. Anderton

Intent - Engaging - Organising

47.1 Learning Outcomes

Engaging undergraduate students in science communication has many benefits. Amongst these is the promotion of students' psychosocial development as they use values to connect science discoveries with their lives and those of their audience. This exercise walks students through a values affirmation intervention in which they identify and reinforce their own values, anticipate the values of their target audience, and then apply these shared values to the framing of a science message. By engaging in this exercise, students develop a better understanding of the role that personal values play in effective science communication. They also benefit from an intervention that has been shown to improve student academic outcomes.

At the end of the activity, students will be able to:

1. Identify and articulate their own values around a scientific issue
2. Identify values that they share with a target audience
3. Craft a values-focused science communication message for a specific audience

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47.2 Teaching Context

This exercise can be used in advanced majors and non-majors science courses. It can be performed in class or as a blended activity in which the first stage is completed before class.

This advanced exercise assumes student familiarity with the concepts of science communication goal setting, identifying a target audience, and framing. This exercise can be modified and expanded to incorporate deeper explanation of these concepts (see Relevant Theory Chapters, below, for suggested exercises).

47.3 Overview of the Teaching Activity

This exercise consists of two stages: (1) a values affirmation task and (2) a values framing and communication task. These two stages can be conducted sequentially in the same class session, or they can be conducted in separate class sessions. Furthermore, they can both be conducted as homework exercises. The lesson plan below assumes that they are conducted as an in-class activity in a single class session.

The values affirmation task is an individual-level activity in which students answer a series of questions asking them to reflect on their own values, identifying those that are most significant to them. This activity takes ~20 min and is done in writing.

Following this activity, students are asked to choose a science topic discussed in class, identify a target audience, and think about how they will communicate the information in a way that reflects their own values and relates to those of their audience. Students brainstorm with their peers how they can best frame their chosen topic to maximize shared values with their intended audience (~25 min). As they do this, students also have an opportunity to clarify any misunderstandings that they may have of the science topic that they chose for the exercise. Students then write a short script (~200 words) that they submit at the end of the class (~15 min; it can also be done as homework).

47.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Introduce the exercise and explain its purpose. Give students the worksheet for the values affirmation exercise (1,2).	Work individually, completing the worksheet as they reflect on their values	The values affirmation worksheet (3) 25 min

Ask each student to pick a topic covered in class that they would like to use for the science communication exercise. Provide guidance to students in (i) identifying target audience(s) and (ii) considering how their values will influence the way they communicate the topic (4).	Use recent class material to find a topic of interest. Based on the selected topic, identify a target audience for their communication message. List shared values between themselves and their target audience that they will use to generate their message.	Recent class material. Whiteboard to record discussions around potential audiences 15 min
Ask students to form groups and discuss their ideas and proposed framing with their peers. Encourage students to spend time describing their values to each other. Also encourage them to ask any questions about the science content that they may be unsure about.	Work in groups of 3 or 4, taking turns sharing their top values, discussing the scientific topic they chose, identifying the shared values between themselves and their target audience, and the way they will incorporate those values into their final science message.	Paper, coloured pens (5) 25 min
Ask students to write their "script" indicating the science topic, the intended audience, and the values they used to frame their message for their intended audience.	Students write their intended script (~200 words).	Tools to record writing 15 min
Total duration in-class = minimum 80 min if done in a single class session. Additional out of class extensions are possible to reinforce the material and values affirmation (6-7).		

Notes

(1) The values affirmation worksheet can be completed on paper or using an online submission platform—choose the form that best suits your class. Additional values affirmation resources can be found at: https://characterlab.org/activities/my-values/; https://equitablelearning.org/books/dyY6m2Bi/McBkpqjr/w8TvGMfA

(2) It is important to emphasize that there are no right or wrong answers when completing the values affirmation worksheet and that the worksheet will be graded for completion.
(3) Appendix 48.1 shows the worksheet for the values affirmation task. We recommend assigning the questions in the "Treatment exercise", which has students identify their top values.
(4) We recommend that instructors read the following article to understand how values relate to science communication: https://issues.org/communicating-the-value-and-values-of-science/. In addition, instructors may wish to share the following accessible article with their students ahead of the exercise, to introduce the concept of values in science: https://theconversation.com/rather-than-being-free-of-values-good-science-is-transparent-about-them-84946. Additional peer-reviewed resources are included in Further Readings below.
(5) A method to write and draw can be useful here.
(6) Following the class activity, you may choose to add additional tasks that can increase the impact of the activity. For example, you could (a) ask students to write a reflection on the activity itself or (b) tell students to deliver the script to an intended audience and then write a reflection on the outcome of the experience and the reaction of their audience.
(7) The activity can be used whenever you want to engage the class with scientific concepts in different contexts—this means you can repeat it at different times during a program of learning.

47.5 Top Tips for New Instructors

1. Students sometimes struggle to engage with the values affirmation exercise as they don't see the relevance to their science course or materials. We suggest that the instructor remind students that science influences our daily lives and that while scientific facts may be objective, the way we communicate these facts to the general population can have a huge impact on how these facts are interpreted and the decisions that the population makes.
2. Some science topics lend themselves better to this exercise than others. Students may struggle to identify a class topic that they feel they can communicate or that they think other people may be interested in. Providing real-world examples of successful values-based science messaging at the beginning of the class can help students who are struggling to envision the outputs of this exercise.
3. An additional way to engage students in this exercise is to identify communication platforms that they use in their everyday lives. For example, common social media platforms such as Instagram, Facebook, YouTube, and Snapchat could be incorporated into the planning and delivery of the final message so that the exercise feels more relevant to how students engage with the world.
4. Students may struggle to identify potential audiences. You can provide examples for the students, including student peers outside of the class, family members, followers on social media, readers of a local newspaper, or community members

(e.g. church members). Students may also consider engaging different age groups—how might they frame a message for older versus younger audiences? It may also be useful to reassure students that their audiences can be as small as one or a few people or as big as hundreds or thousands—all sizes can have an impact!

5. Similarly, students may struggle to honour and embrace their values while connecting with the values of a target audience. The instructor may wish to provide examples of successful values-driven messaging, such as environmentalism, health, or community-centred messages.

Further Reading/Exercises

Dietz, T. (2013). Bringing values and deliberation to science communication. *Proceedings of the National Academy of Sciences, 110*(Supplement 3), 14081–14087.

Jordt, H., Eddy, S. L., Brazil, R., Lau, I., Mann, C., Brownell, S. E., . . . Freeman, S. (2017). Values affirmation intervention reduces achievement gap between underrepresented minority and white students in introductory biology classes. *CBE—Life Sciences Education, 16*(3), ar41.

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Seethaler, S., Evans, J. H., Gere, C., & Rajagopalan, R. M. (2019). Science, values, and science communication: Competencies for pushing beyond the deficit model. *Science Communication, 41*(3), 378–388.

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Identifying Personal Beliefs and Values Through Group Sense-Making

48

Christine Adams and Colin Jones

Intent - Investigating -Distilling

48.1 Learning Outcomes

Graduates increasingly encounter a world characterised by super complexity, where their ability to understand their environs and their own responses to situations is of paramount importance. In addition, the ability to articulate one's values, beliefs and feelings is crucial in the workplace to enable careful judgement, creative thinking and decision-making.

In this chapter we outline a process of group sense-making in which students can practice being vulnerable by examining and articulating their responses to situations, events or ideas.

Acknowledging the inherent challenge of drawing students into the uncomfortable space of questioning their assumptions, this exercise is designed to enable students to focus on their values, beliefs, feelings and experiences rather than trying to achieve the "right" response. After completing this exercise, the student will be able to:

- Identify their values, beliefs and feelings relative to a situation statement
- Compare and contrast their values, beliefs and feelings relative to the diversity present in their study cohort

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- Articulate values, beliefs and feelings that incorporate a diversity of perspectives and adjust their judgement as required
- Critically reflect on the nature of any change in their values, beliefs and/or attitudes during the exercise

48.2 Teaching Context

We have successfully used his reflection exercise in undergraduate and postgraduate contexts. The provenance of this reflection process was a face-to-face exercise for nursing students, but as presented here, it is suitable for students in all discipline contexts and is developed for online delivery (Jones, 2009).

It is important to ensure the participants understand they will be objectively assessed on their level of engagement with the process (as opposed to being subjectively judged on the feelings they express or the outcome of the exercise). In many science-based contexts, this point needs to be emphasised to ensure students fully appreciate both the purpose and process of the activity.

Students can find this exercise confronting. It asks them to move from a position of certainty (and an unquestioning sense that their viewpoint is universalistic) to a more dialogical, multiple-understanding way of being and knowing. This may cause learners to experience excitement and/or apprehension. New ways of being and knowing (i.e. new frames of reference) may put the learner at risk of being out-of-step with colleagues, peers and cultures in which they have invested. The student's previous frames and connections will have sustained them, and they may continue to sustain them at some level. Thus, it is important for educators to highlight how investigating and distilling deeply held assumptions can help people articulate their frame of reference (and understand the frames of other people). In turn, this helps them create better guidelines for action, improve their professional practice and develop a more ethical and compassionate stance.

New educators working in cross-cultural learning environments may expect a diverse array of responses to situation statements and potentially some discomfort where students have not previously engaged deeply with their values and beliefs. Educators are encouraged to work with a mentor when first using this activity and consider debriefing techniques for themselves.

48.3 Overview of the Teaching Activity

To start the exercise, the educator designs a (provocative) *situation statement* to elicit a deep emotional response about a specific industry and societal situation. An example could be: "Carbon farming decreases greenhouse gases as pastures are closed to stock, letting native vegetation grow and absorb gas emissions. This will generate income for farmers in the long term through carbon tax credits. However, many farmers question the viability of sustaining their livelihoods, farming traditions and the broader farming communities". Having read the statement, students complete the following four phases:

Phase 1: Students document the personal feelings they recognise after they read the statement. Students can record multiple feelings. These should include both assumed and actual feelings.

Phase 2: Students review each other's recorded feelings and compare and contrast their own feelings to others in the class. At this stage, the aim is to reflect on differences observed, and to arrive at an interim conclusion, as to how this situation statement relates to personal values and beliefs.

Phase 3: Each student validates their analysis of the situation by asking for feedback from other (external) participants or peers. This work is done to determine if the feelings they attribute to the situation statement are confirmed by reference to the ideas and perspectives of others (i.e. to "sense check" their feelings with a non-student audience). This phase may also elicit additional personal reflections that can help the student sense-make.

Phase 4: Each student reflects on the extent to which the process has influenced their approach to and/or perspective on the specific issue. Students note any shift in their values, beliefs, attitudes or general understanding.

48.4 Runsheet and Lesson Plan

Preface: A situation statement outlines a *current problem* or dilemma *to be solved* or *explored*. The situation statement should be designed to be provocative to ensure that different responses are elicited from the class cohort. It could be written (as described below) or in video form.

Before the exercise begins, explain the purpose of the exercise with students. Share the task description and marking rubric with students as well.

The instructions below are written directly to the instructor and the students; the instructions assume the class has an LMS (Learning Management System) with a Discussion Board and/or Blog function. You may also choose to run elements of this activity in a face-to-face format.

Pre-activity
Instructor: Develop the context-specific Situation Statement (1). Here is another example: *"Public engagement must happen in places and on issues that are inconvenient, emergent, or marginal rather than in well-defined scientific communities".* *Resources:* Post this statement and the exercise instructions on the class LMS.
Phase 1: identify Feelings
Students: After reading the Situation Statement, reflect on your THOUGHTS and FEELINGS when reading the Situation Statement (2). In the open (Phase 1) Discussion Board area of the class LMS, document the nature of your THOUGHTS and FEELINGS and provide a short explanation of each feeling. The following questions may be useful for your reflections. Please remember to focus on your actual thoughts and feelings, not the things you assume you *should* be thinking and feeling: *What are your personal thoughts, feelings and comments regarding this statement?* *Thinking beyond your first response, what other thoughts and feelings do you have?* *What specific values and beliefs do these feelings and thoughts represent?* *Your thoughts and feelings may change over time, why could this be so?* *Resources:* Open Column in Discussion Board on LMS
Phase 2: Search for Meaning
Students: Read the contributions of about 20+ class members in the open column of the Discussion Board. Then, COMPARE and CONTRAST your values, beliefs and feelings with your class members in the private area of the Discussion Board of the class LMS. Conclude by writing your explanation of: *What are the values, beliefs, thoughts and feelings of your class members in relation to the situation statement?* *How do others' beliefs and experiences relate to your own?* *What does the contrast or congruence with the class members mean to your perspective?* *Resources:* Private Column in Discussion Board on LMS

Phase 3: Validate
Instructor: Ask your students to seek validation of their thoughts by sharing the original Situation Statement with persons external to the class (3). *Students:* Show the Situation Statement to someone not in your class. Ask them: *Do they agree or disagree with the situation statement based on their values, beliefs and feelings?* *How did they explain their ideas to you?* *Consider, does their reply validate your beliefs, values and feelings in relation to the statement?* *What do you think about your responses to the question now?* In the private (Phase 3) area of the Discussion Board of the class's LMS, explain why you are "sticking" with your original sense of what your thought or felt when you read the situation statement means, or why you might have modified your stance. *Resources:* Private Column in Discussion Board on LMS
Phase 4: Identify Change
Students: In the private (Phase 4) area of the Discussion Board of the class' LMS, conclude by commenting on the extent to which your attitudes, values, beliefs or general understanding have been altered whilst completing the group sense-making task. *Resources:* Private Column in Discussion Board on LMS
Assessment
Instructor: Mark the student submissions using the provided rubric (4).
Total duration in-class = *60 minutes + 180 minutes* for activity to be completed outside of class time.

Notes

(1) Provocative situation statements are more likely to create or stimulate divergent views within and between student groups and encourage "unsettling" experiences that drive learning.

(2) The goal here is to get students to consider what they are feeling and why they are feeling it. Some additional prompts for students could be: Why do you feel this? Do you actually feel this, or do you think you *should* feel it? Did you feel this and then reconsider? Do you think this feeling is appropriate?

(3) Students report that having the opportunity to see their own values through a third person perspective is very useful to overall learning.
(4) Rubric

	Distinction 100% - 71%	Pass 70% - 50%	Fail 49% - 0%
Phase 1 Identify Feelings	Several feelings derived from deep consideration of the situation statement are noted. Short explanation provided for each feeling linked to values and beliefs. Thinking about feelings is very clear.	One or two feelings derived from considering the situation statement are noted. Short explanation provided for each feeling linked to values and beliefs. Thinking about feelings is present.	Little if any attempt to identify personal values, beliefs and feelings.
Phase 2 Search for Meaning	All noted values, beliefs and feelings are compared and contrasted with those noted by peers. Student makes a clear and concise statement around what this contrast or congruence with others means to their own perspectives. Thinking about others' feelings is very clear.	Most noted values, beliefs and feelings are compared and contrasted with those noted by peers. The student provides a statement around what this contrast or congruence with others means to their own perspectives. Thinking about others' feelings is present.	Little if any attempt to compare and contrast values, beliefs and feelings and/or state what this contrast or congruence with others means to their own perspectives.
Phase 3 Validate	An interpretation of the situation statement by an external person is provided. The degree of validation of the post-Phase 2 thinking is clearly explained with reference to external opinions. Thinking about others' thinking is very clear.	An interpretation of the situation statement by an external person is attempted. Some degree of validation of the post-Phase 2 thinking is presented with reference to external opinions. Thinking about others' thinking is present.	Little if any attempt to seek and/or explain external validation.

Phase 4 **Identify Change**	The nature of any change (or otherwise) to attitudes, values, beliefs or general understanding is explained. Thinking about thinking is very clear.	The nature of any change (or otherwise) to attitudes, values, beliefs or general understanding is addressed. Thinking about thinking is present.	Little if any attempt to explain the nature of change (or otherwise).

48.5 Top Tips for New Instructors

1. The exercise requires that students engage with—and bring their values, beliefs and feelings to—the learning experience. It encourages learners to become aware of others' values and beliefs whilst also challenging their own pre-existing assumptions and ways of viewing the world.
2. For this exercise to succeed, it is important to nurture the students' sense of critical reflection (O'Loughlin & Griffith, 2020). This includes an awareness of how one's values, beliefs and experience may influence knowledge-making, decision-making and behaviour.
3. Collaboration helps learners shift their frame or incorporate more ideas into their framing (Tversky & Kahneman, 1981). When students collaborate, their group-level frame is built of individuals' frames. Thus, students' individual frames and interactions may shift the group framing, potentially moving the activity closer or further from sense-making. You may want to ask students to consider whether they are engaging in "groupthink" as they adjust their ideas. There are many useful online resources to help you and your students consider the groupthink phenomenon.
4. Student frames may even interfere with one another, and so students may have to verify their individual frames in order to progress in their task. They can do this by validating their frames against those of others and, ultimately, by negotiating and co-constructing a shared or new frame. This practice of external validation helps reduce groupthink. The negotiating work is more easily done in person—you may wish to include an in-person workshop at some point in this exercise.

References

Jones, C. (2009). Enterprise education: Learning through personal experience. *Industry and Higher Education, 23*(3), 175–182.

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Finding Your Authentic Voice

49

Alice Motion and Ellie Downing

Intent - Speaking - Engaging

49.1 Learning Outcomes

This activity highlights the value of diverse voices, perspectives and identities when sharing science. It challenges students to find their authentic voice for oral presentations. It also embeds the idea that adopting an authentic communication persona is central to effective communication of science.

On completion of this activity, students will be empowered to be more authentic, effective, adaptable and confident communicators of science. The work challenges students to identify the aspects of communication that come most naturally to them, those that they enjoy and those that require further work or development.

49.2 Teaching Context

This activity will help students to gain confidence in oral communication. Students will learn to critically evaluate their own, and others', oral presentations and communication.

We have used parts of this activity with PhD and senior undergraduate students. The students have been preparing for assessment presentations, conference talks, science communication competitions and public lectures.

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This activity can be adapted for use with students of all stages but works best with senior students who already have some science communication experience.

49.3 Overview of the Teaching Activity

The activity begins outside of class where students are asked to introduce themselves, note their favourite science communicators and explain the reason for their selection. They watch some different examples of science presentations and reflect on the different styles of communication and their own preferences.

In class, students share some of their perspectives and are then guided to reflect on the things they would most like to develop about their own science communication. We explicitly highlight the importance of finding their own authentic voice rather than emulating styles of communication that are not comfortable for them. Individual students share their reflections anonymously using polling software or discussion boards which expands into a whole-class discussion.

Authenticity is the quality of being real, genuine or true. This activity seeks to empower students to develop their own voice and unique style of communication. By observing and critiquing the communication styles of others and themselves, they become more attuned to their individual communication style and identify their own areas for development.

The cohort then work together to develop a class rubric to assess an upcoming presentation assignment that builds in some of the areas highlighted by the class, focusing on identifying a way to assess authenticity. Next, students draft a short presentation on an assigned science topic and present a draft to their peers and then provide each other with feedback. Students then use peer feedback to improve their presentation and write a reflection based on the peer feedback exercise. In the final session, students take it in turns to share their final presentation with the class and engage in peer evaluation.

49.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Prepare class discussion board which invites students to introduce themselves and share details of their three favourite science communicators and the reasons that they enjoy their work (1).	Complete the discussion board introduction (1).	 15 min

Instructor does…	**Students do…**	**Resources**
Share three short video clips of presentations on related science topics (2) from science communicators with different communication styles (e.g., humorous, formal, relaxed) and from a diversity of backgrounds. Share worksheet with prompts including factors such as tone, script, pace, structure, body language, rhetoric, language, slides, etc. (1)	Students watch the videos and note down observations as prompted by the worksheet along with their own thoughts and perspectives. Students are then asked to identify their preferred presentation style and to give reasons for their preference (1).	Worksheet, links to video items selected by instructor. Appendix 1: Worksheet 45 min
Invite students to share their favourite piece of communication or communicator from the examples. Invite students to reflect on representation in science communication, whose voices they choose to engage with in this space, and why (3).	Take part in class discussion (3).	15 min
Introduce a self-reflection exercise, then help to draw out the different perspectives from the class and identify the elements that students have collectively identified as being most important for effective oral communication (3).	Identify the situations, audiences, topics etc. that make them feel most and least confident when communicating science. Highlight three key things they want to develop in their own communication; share using anonymous polling software (3).	Polling software e.g. Mentimeter or Socrative. 15 min
Facilitate guided conversation and rubric development where students: - acknowledge the importance of different communication styles - define the objective and subjective aspects of a good oral presentation and - emphasise the importance of authenticity (3).	Together with the instructor, devise a class-designed science communication 'rubric' for the assessment tasks and critical evaluation that follows (3,4).	Rubric examples. 25 min

Instructor does…	Students do…	Resources
Introduce presentation assignment and ask students to work on drafting a short, ~5 minute presentation on a designated science topic pertinent to the Unit of Study. (3)	*Outside of class:* Prepare a draft presentation in advance of the next class. In particular, focus on the three areas they chose for self-development and the rubric co-designed in class. (1)	5 min in class; 60 min outside class
Divide students into small peer groups, where students turns to perform their presentation to each other and provide peer feedback (5).	Perform their presentation to each other. Provide peer feedback, particularly on each other's focus areas for improvement and authenticity (5).	60 min
Give students guidelines for their reflective work.	Write reflections on their presentation and peer feedback with a particular focus on the three areas selected for self-development and authenticity (1,6).	60 min
Facilitate presentation session.	Students perform their final presentations and are peer-marked according to the class rubric (3).	60 min
Total duration in-class = 120 min + 120 min outside of class, run over three one-hour sessions with 1 hour of homework/preparation in advance of each class.		

Notes

(1) This activity occurs outside of class as preparation for in-class activities.
(2) Choose presentations that are pertinent to the disciplinary context of your teaching or a range of science disciplines if you are teaching a broader science communication class.
(3) This activity occurs during class time.
(4) Instructor can choose how much of the rubric should be 'co-designed' in class, but class input on the criteria for assessing authenticity should be sought.
(5) Students are encouraged to record each other on mobile phones so that they can watch their own presentation later.

(6) Students identify the things that they like about their own presentation and the things that they wish to improve and use this reflection to further refine their presentation.

49.5 Top Tips for New Instructors

1. Students may not be able to identify styles of science communication that feel authentic for them. Highlight that this is OK and that they may choose instead to seek inspiration from presentations by people outside of science.
2. Creating a rubric from scratch with a class can feel quite daunting/time consuming. Scaffold this exercise by sharing a partly completed rubric and asking for student input on just one criterion if this feels better to you.
3. Sharing your own opinions or the things that you find challenging can be a great way to build connections and your own authenticity with students.
4. This activity can be altered to work for any medium of science communication. For example, finding their 'voice' as a writer. You can encourage students to reflect on what they've learnt about their own voice and style when presenting and how they could apply this to other forms of communication.

Website Links

Designing Rubrics for Better Assessment. https://itali.uq.edu.au/files/1234/Discussion-paper-Designing-Rubrics-For-Better-Assessment.pdf. Accessed 5 Feb 2021.

CLIPS (Communication Learning in Practice for Scientists). https://www.clips.edu.au/. *Accessed 1 Jan 2021*

Resources

Appendix 49.1 Worksheet—Finding Your Authentic Voice.

This appendix is also available as Worksheet 3 at this location: https://bit.ly/SCOPE_TSSTC, Accessed 22 July 2021.

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Communicating for Inclusion: Using Powerful Images and Language to Support Diversity in Science

50

Cate Thomas, Patricia Logan, Chelsea Litchfield, and Denise Wood

Intent - Conversation - Working

50.1 Learning Outcomes

Students often respond to situations based on their own positionality (i.e. their own world view). This may result in miscommunications. It can also result in incorrect, simplistic, or self-centred interpretations of situations. This chapter provides a stepped activity (and an ongoing tool) for students to expand their ideas around inclusive practice. This helps them become reflexive and critically conscious of their own positionality and to the need for honouring diversity as they communicate.

50.2 Teaching Context

The activity helps students to reflect on, build awareness of, and develop an understanding of identity characteristics that can either lead to disadvantage or privilege depending on place, time, and location. As a result, they view themselves

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S. Rowland, L. Kuchel (eds.), *Teaching Science Students to Communicate: A Practical Guide*, https://doi.org/10.1007/978-3-030-91628-2_50

and others more holistically. It can be used as a hurdle activity for students before they embark on workplace learning, clinical placements or investigations and research. The tasks are appropriate for assessing students' suitability to effectively work within a diversity and intersectionality context in the practice environment. This activity is relevant for all forms of studies and courses.

50.3 Overview of the Teaching Activity

Language and images are powerful tools for both inclusion and exclusion of others. Consequently, it is important to increase our awareness of the words and images we use and their potential impact on an audience. This activity has three distinct components that may be used individually or as a group of stepped activities.

1. *Reflection*—Students use reflective journaling to develop an understanding of positionality, privilege, and reflective thinking for practice. By examining multimedia resources independently and in groups, students come to understand how their own positionality may impact on their communication and practice.
2. *Images in Science*—Students analyse images in science and critically reflect on questions that examine the common or disparate characteristics of individuals and groups. They examine assumptions about how gender, race, age, and disability are represented within a group of people and the potential impact of omitting individuals from the group.
3. *Language in Science*—Students work in small groups to undertake critical reflection to (i) reveal the impact of language on inclusive conversation and (ii) identify ways they will intentionally use language to respect and value others. The activity uses common terms and phrases to invite debate on avoiding unintentional bias.

50.4 Runsheet and Lesson Plan

The reflective component of the activity is broken into two parts (A and B) to 'bookend' the activity. The reflective journal is used in all parts of the activity.

PART 1: Reflection Part A (30 min)

Resources: Internet access; Students bring notebook to use as a journal: listed references.

Introduction

Instructor welcomes students and asks students to have a notebook or word document open to jot down thoughts, observations, reflections, and responses to questions during the activities.

Present the Positionality Definition and discuss – ask students to reflect on the concept of positionality (1).

Model

Instructor (if comfortable) gives an overview of their own positionality and privilege as an example and discusses what positionality means broadly (and if comfortable, personally).

Guided learning

Instructor asks students if they have thought about how their lived experience impacts on how they see the world

Present Understanding Privilege

Students watch the video and write down their understanding of positionality and privilege, and then what their personal positionality is. They break into groups of 3-4 and discuss how positionality and privilege impact them.

Independent learning

Instructor discusses why it is important to reflect on one's own positionality in practice and research (we all consciously and unconsciously have an impact on how we communicate). Encourage students to use a journal to record and work on individual areas for development.

Present Understanding Reflective Practice

Discuss

Instructor leads discussion on reflective practice, including the Reflective Writing format of Describe, Interpret, Evaluate, Plan (DIEP) putting positionality at the centre of reflection.

Students write down how they can use DIEP in reflective practice.

PART 2: Images in Science (45 min)
Resources: Internet access to the Australian Academy of Science webpage (2) and the Makarova and Herzog (2015) reading. **Model** *Instructor* asks students to access the Australian Academy of Science website, look for the governance structures and access the list of past presidents: https://www.science.org.au/ and https://www.science.org.au/about-us/governance/president *Students* examine the governance structures and list of current and past presidents of the Academy of Science by reviewing their biographies and images to identify represented groups. **Guided learning** *Instructor* briefly discusses with students the purpose of governance structures and impact of privilege and lack of diversity. Use James, Chisnall and Plank (2019) to guide this discussion. **Independent learning** *Instructor* asks students to discuss the board membership and president list in terms of group representations (diversity, gender, ethnicity, disability). *Students* in small groups: - Identify 5 characteristics that describe this group of people. - Look for similarities and/or differences between the individuals in this group - Consider which (if any) groups of people are poorly represented in this list - Consider what assumptions (including false assumptions) we make about these individuals and this group and who they represent. *Instructor* engages students around these questions: - How might we encourage greater diversity in leadership positions? - How might governance structures support increased representation? **Reflection** *Instructor* asks students to record their responses in their journals. *Students* use the Makarova and Herzog (2015) article (3) to guide their journal reflection about how this activity has influenced their approach and understanding of representational images.

PART 3: Language in Science (45 min)

Resources: Access the resource Language in Science

Model

Instructor models use of language by greeting students with the statement: *Hello guys, dolls, and the rest of you! Here we all are, ready to consider how the language we choose to use can serve to either include or exclude others. So, shimmy yourself into a seat and let's begin.*

Ask how this greeting may be considered problematic by some persons.

Students respond to instructor question (4).

Guided learning

Instructor asks students to read Activity 1 statements silently.

Students read the statements. In groups of 3, students identify how the statements may alienate various groups, and how they influence respect and valuing individuals. Each group suggests alternate ways of expressing the idea.

Independent learning

Instructor uses Activity 2 in the resource. Select individual students to read the headings and facilitate a 3-4 minute discussion about the appropriateness of the headings. Divide students in groups of 4-5. Allocate two newspaper headings to each group.

Students, with the allocated two headings:

- Analyse the language. Ask (i) What is problematic about the language choices here? (ii) Which groups of people may feel alienated?
- Re-write the headings to increase inclusivity and remove bias providing rationales for choices. Report to the whole class.

Reflection

Instructor asks: What impact will these exercises have on the choices you make when speaking or writing for a broad audience?

Students reflect in their journal.

PART 4: Reflection Part B (30 min)
Reflection *Instructor,* upon conclusion of all activities, invites students to reflect on how positionality and reflective practice impacts professional or social activities by asking: 1. Have the activities changed your thinking about your own positionality or your understanding of inclusion and diversity? Why and what changed? 2. What does this mean for your practice when going out on work placement, undertaking research, or in a social situation? 3. Why is it useful to have a reflective journal? *Students* participate in discussion, then write a final journal reflection on: 1. Their journey throughout this exercise - what changed (D), what happened to make it change (I) why did it change (E) and how you will use this in the future (P). 2. How reflective journaling assists individuals as a tool for lifelong practice of professional and inclusive behaviour.
Total duration in-class = 150 min + 30 min pre reading time

Notes

(1) This exercise may be confronting for students when discussing privilege and positionality. Not all students will want to disclose this information. It is important to do the activity understanding that individuals will have different lived experiences, identity characteristics, and comfort with disclosure.

(2) Created in 1954, the Australian Academy of Science consists of Australia's leading research scientists. The academy 'promotes international scientific engagement, builds public awareness and understanding of science, and champions, celebrates and supports excellence in Australian science' (science.org.au, 2021).

(3) Students pre-read Makarova and Herzog (2015) to help them reflect.

(4) This activity indicates the students' awareness of language use.

50.5 Top Tips for New Instructors

1. The best way to approach this exercise is for instructors to immerse themselves in the activities prior to delivery.
2. Ideally, all activities are done sequentially, however, each or any can be done independently or in any combination.

3. It is better to hold this session in a room where there is freedom to move into groups and configure tables for small group work.
4. A useful way to create random groups for discussion is to number students 1-5, and all 1s work together etc. Numbered groups can be further divided if too large.

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Makarova, E., & Herzog, W. (2015). Trapped in the gender stereotype? The image of science among secondary school students and teachers. *Equality, Diversity and Inclusion an International Journal, 34*(2), 106–123. https://doi.org/10.1108/EDI-11-2013-0097

Further Reading/Exercises

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Rogers, A. (2020). Gender – diversity – intersectionality: (New) perspectives in adult education: Martina Endepohls-Ulpe and Joanna Ostrouch-Kaminska (eds). Waxmann, Münster/New York, 2019, 215 pp. ISBN 978-3-8309-3883-5 (pbk), 978-3-8309-8883-0 (eBook). *International Review of Education, 66*(1), 123–125. https://doi.org/10.1007/s11159-019-09818-w

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Further Intersectionality Walk resources from Thomas et al; can be found at: Resources – Science in Australia Gender Equity (SAGE) (sciencegenderequity.org.au) under the heading An Intersectionality Walk, with structural change (SAGE ACT Regional Network).

Website Links

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Understanding Privilege - YouTube. (https://www.youtube.com/watch?v=jLsPxFB7-qg). *Accessed 19 Jan 2021*

Understanding Reflective Practice - YouTube. (https://www.youtube.com/watch?v=iBmtH0Qx0YU). *Accessed 19 Jan 2021*

Reflective-Writing.pdf (csu.edu.au). (https://cdn.csu.edu.au/__data/assets/pdf_file/0020/830360/Reflective-Writing.pdf). *Accessed 19 Jan 2021*

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Part X

Practice Genre

51 The Genre Switch Game: Tailoring for Audience and Format

Ellen K. W. Brennan and R. Keith Duncan

Genre - Engaging - Storytelling

51.1 Learning Outcomes

Genre is an essential concept in the arts, where it describes the collaborative relationship between artist and audience. Genre gives the artist structure and the audience familiarity, raising impact where they meet. So, too, in the sciences! Students of science must also frame concepts within varying genres, whether based on audience (i.e. general public or scientific peers) or format (i.e. TEDx talks or grant proposals). In this lesson, students will gain an understanding of genre in the sciences, learn how to relate genre to communication modes, and examine how adopting genre conventions—and sometimes deviating slightly from them—can impact the efficacy of their message. The lesson incorporates an interactive improvisational activity with written assignments to train students as flexible, effective communicators.

51.2 Teaching Context

This activity introduces students to the different factors of genre that apply within the sciences and how leveraging that knowledge can increase the success of writing and speaking activities. It is suitable for students from secondary to graduate school.

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We have completed this activity in 1.5-h workshops with neuroscience PhD students as well as in 50-min workshops for interdisciplinary PhD and postdoctoral fellows across the sciences. The activity requires approximately 10 min for introduction, an additional 2–3 min per student for the Genre Switch Game, and 5–10 min for debrief. It has also been successfully adapted for both in-person and virtual formats.

51.3 Overview of the Teaching Activity

The lesson begins with an interactive discussion on the definition of "genre", rooted in familiar conventions in literature, music, and art. From there, we ask students to explore how the concepts used to define genre, such as theme, scope, and audience, relate to various forms of science communication. Discussion will end with a definition of "genre" in science, technology, engineering, and mathematics (STEM) and suggestions from the students on genres to be used in the Genre Switch Game. The game consists of a speaker and audience component to keep students engaged at all times. The speaker will give a brief (~3 min) informal talk on a chosen topic, switching their approach periodically to accommodate new genres from the list previously generated. During the talk, the audience members can provide real-time feedback by holding up a green "AWESOME" card when the speaker is addressing their genre well or an orange "ADJUST" card when the speaker needs to adjust their approach. After the activity, there is a guided debrief discussion to help students reflect on the intentions of the exercise and lessons learned. Lastly, an evaluation exercise is assigned as written homework for students to practise the skills they acquired in the exercise. Example genres, definitions, topics for speakers, debrief discussion questions, exit exercise, and rubric are included in the Genre STEM Switch Guide, linked below.

51.4 Runsheet and Lesson Plan

A detailed template for this lesson plan and the accompanying discussions and assignments can be found in the Genre STEM Switch Guide by following the first link in the Website Links section. We highly recommend instructors to follow this guide the first time they implement this exercise.

Instructor does…	Students do…	Resources
Lead introductory discussion on the concept of genre.	Suggest types and conventions of familiar genres and extend this to common science communication formats. Form a list of STEM genres (2) and display for reference during the game.	The Genre STEM Switch Guide (1) 10 min
Explain the Game and define speaking topic options (3), establish ground rules for engagement (4), assign roles (5), hand out Feedback Cards (6)	Students accept roles and acknowledge the ground rules.	The Genre STEM Switch Guide (1) 5 min
Model the Genre Switch Game.	One student facilitates instructor's model talk, remaining students provide live feedback using feedback cards.	Genre list made during introduction; timer 3 min
Facilitate the Genre Switch Game.	Participate in the Genre Switch Game as: [A] Speaker [B] Audience member giving real-time feedback.	Timer; feedback cards (6) 30+ min (7)
Facilitate debrief discussion.	Participate in debrief discussion.	The Genre STEM Switch Guide (1) 10 min
Extension Exit Ticket assignment (8).	*Extension* Students provide summative feedback on cards as exit tickets.	Index cards or post-it notes 5 min
Extension Science Through Storytelling Worksheet	*Extension* As a homework assignment, students extend their exploration of genre to write a folktale version of their science topic.	Science Through Storytelling worksheet (9) 20+ min
Total duration in-class = 60+ min [+ 20 min for optional storytelling extension activity, if included].		

Notes

(1) The Genre STEM Switch Guide provides a template for the entire exercise and should be followed closely to ensure students get the most from this game (see Website Links section). The Guide begins by including introductory discussion questions, example definitions of genre, an example list of genres, and suggestions for sources of content for the brief informal talks given by each speaker. The Guide also provides questions to facilitate the debrief discussion as well as examples of key lessons and applications learned from the activity.

(2) Students should create a list of STEM-focused genres during the introduction discussion, as outlined in the Guide (1). The three main classes of STEM genres are Audience, Problem, and Format. Some example STEM genres are grant reviewers, 3rd graders, hiring committee, grandparent, policymakers, the public, scientific article, news article, and Twitter post.

(3) Example materials that students can address in their brief talks are a recent lab exercise, an experiment or finding discussed in class, a scientific article/journal club, or their research project.
(4) In order to create a supportive environment, it's critical to establish ground rules for engagement. See Guide (1) for examples, such as using inclusive language only and not negating other's contributions to discussion.
(5) Assign roles as explained in the Guide (1). The main roles in this exercise are Facilitator (often held by the instructor), Speaker, and Audience. Additional roles of Timer and Genre Master can be added to increase engagement.
(6) The feedback cards can be made in multiple ways, so anything available and affordable for the instructor is encouraged. In the past, we have printed sheets of paper that had the word "AWESOME" in green text on one side and "ADJUST" in orange text on the other. We have also used green and yellow index cards, where green signalled that the speaker was addressing their genre and yellow meant they were not meeting their genre. For both of these examples, students would raise the card that represented their evaluation of the speaker's current performance accommodating the assigned genre. When using this exercise online, we provide students with two virtual backgrounds—one was green with the thumbs-up emoji, and the other was orange with the shrugging emoji. Students kept their cameras on and changed their virtual background to reflect how well they thought the speaker was doing.
(7) The total time spent playing the Genre Switch Game will vary depending on class size. Assume 2–3 min per student speaker with a 1-min transition between speakers.
(8) At the end of the activity, ask students to retrieve their feedback cards. On their cards, they should write their name and answer the following prompts: "1. Provide a definition of genre in STEM," and "2. Which STEM genre(s) did you find most difficult to use, and why?" Students should receive full credit if their definition incorporates the concept of (1) an agreed-upon set of conventions and (2) that genre involves both communicator and audience being familiar with those conventions.
(9) Students can complete the Science Through Storytelling Worksheet (see Website Links section) using their Game talk topic. This extension activity brings in concepts of narrative and story protagonists.

51.5 Top Tips for New Instructors

1. We encourage instructors new to the Genre Switch Game to closely follow the discussion prompts in the Guide (1). The introduction discussion is necessary for establishing an understanding of "genre", and the debrief is critical to helping students extract concrete lessons from the game.
2. This activity works best when students do not prepare a talk beforehand and thus must improvise their approach. We suggest not discussing details of the activity with students before it is time to begin. However, we also must consider the

inherent stress and anxieties that often accompany impromptu public speaking. The instructor should use their best judgement when deciding if and how to preview the activity. One option is to inform students that in an upcoming class, they will be practising communicating scientific concepts in an informal and non-graded game. If certain students are unable to participate as a speaker, there are alternative ways for them to engage (see Guide).

3. Students love it when the instructor models the game. It is relieving to them to see the instructor also have to improvise and sometimes struggle to accommodate the every-changing genres. Encourage students to be willing to make mistakes rather than spend their entire 2–3 min tongue-tied.
4. To encourage a supportive and low-pressure environment, students should be allowed to choose the topic for their brief talk from a list of relevant categories supplied by the instructor (3).
5. Often during the Game, energies will rise, and the classroom environment will get a little silly and elevated. This is a fast-paced improvisational exercise, so you can expect students to be nervous, relieved, and likely quite loud at different times. Stay firm in the 2–3-min talk per student time to keep the class on track. Otherwise, embrace the excitement before refocusing for the essential debrief.
6. The Game often inspires a lot of humour, which is part of what makes it such a positive experience for students. However, students should not feel pressured to be funny; instead, they should focus on being flexible and adapting to the different genres.

Further Reading/Exercises

These further reading materials are optional and provide other useful viewpoints and insights into genre within STEM.

Foster, M. D., & Tolbert, J. A. (Eds.). (2015). *The Folkloresque: Reframing folklore in a popular culture world*. University Press of Colorado.

Luzon, M.-J., & Perez-Llantada, C. (2019). *Science communication on the internet: Old genres meet new genres*. John Benjamin Publishing Company.

Website Links

The Genre STEM Switch Guide. (https://deepblue.lib.umich.edu/handle/2027.42/166089). *Accessed 5 Feb 2021*.

Science Through Storytelling Worksheet. (https://deepblue.lib.umich.edu/handle/2027.42/166090). *Accessed 5 Feb 2021*.

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R. Keith Duncan is an Associate Professor of Otolaryngology and a member of the Neuroscience Graduate Program at the University of Michigan. He enjoys incorporating interactive teaching methods in the laboratory and classroom and has been leveraging the philosophies of applied improvisation to augment professional development in science communication.

Creative Podcasting to Develop Content Knowledge and Communication Skills

52

Nancy Longnecker, Mark Pegrum, and Emma Bartle

Genre - Storytelling - Speaking

52.1 Learning Outcomes

This creative podcasting assignment provides an opportunity to develop important graduate attributes as students learn to write and produce a podcast. After completing this assignment, students should:

- Be familiar with characteristics of effective podcasts
- Have experience creating an audio file
- Be familiar with software for editing audio files
- Be aware of copyright issues and permissions needed for use of material produced by others
- Be able to produce an engaging podcast
- Be able to provide and receive constructive feedback

Supplementary Information The online version contains supplementary material available at [https://doi.org/10.1007/978-3-030-91628-2_52].

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52.2 Teaching Context

This podcasting assignment uses digitally mediated science communication to improve both understanding of specific content and skills in creative storytelling. It enables students to engage with concepts beyond rote learning, with the aim of using technology to support constructivist learning (Pegrum et al., 2015) and motivate potentially disengaged students (Bartle et al., 2011).

As a flexible assignment, it has been used successfully from the first year through to the postgraduate level. Thousands of students in disciplines varying from physics and science communication to history have completed it. For example, we have used it in a first-year chemistry class where the instructor identified commonly-misunderstood topics; students were given the brief to produce a short podcast on one of those topics (example podcasts provided as online resources, ESM_1.mp3 and ESM_2.mp3).

52.3 Overview of the Teaching Activity

This assignment involves creating a podcast about content related to the subject of the class. Consider setting topics that would benefit from additional work by students. Provide the assignment handout, discuss the podcast assignment, and highlight features of student-produced podcasts that you will look for when marking.

This creative podcasting assignment supports students in contextualizing content and developing important graduate attributes, including collaboration and oral communication skills. A sample Podcast Marking Rubric is provided as an online resource (ESM_3.pdf).

Consider offering optional help sessions or workshops to assist students who are new to the technology or feel out of their comfort zone. Your University Librarian may be able to assist with providing technological support to students. There are resources and tutorials online if you do not have the capacity to offer assistance on site (for example, see WEBSITE LINKS section).

52.4 Runsheet & Lesson Plan

<table>
<tr><td colspan="2">Before Class</td></tr>
<tr><td colspan="2">Instructor

Determine whether the podcast topics will be set by you or whether the students will have free choice. Decide whether this will be a group or individual assignment and nominate your preferred mechanism of assessment (self, peer, teacher).
Determine what technological support your students need. It is essential that every student or student team has access to a recording device (e.g., a smart phone or laptop) and editing software (whether desktop or app-based; for examples, see WEBSITE LINKS section).
Provide assignment handout/activity description via the course learning management system (LMS) (1).
Find exemplar podcasts in case they are needed (2).
Organise an LMS facility for students to upload links for exemplar podcasts, to engage in sharing and discussion, to submit their completed podcasts, and optionally to give and receive peer feedback.
Students
Search online to identify exemplar podcasts; provide links for class discussion (3)</td></tr>
<tr><td colspan="2">Introductory class (45 min)</td></tr>
<tr><td rowspan="2">Instructor

Provide a brief introduction to podcasts and the learning objectives of the exercise (4).
Lead class discussion about more and less effective exemplar podcasts and draw out discussion about storytelling (5).
Students
Participate in discussion and seek any clarification needed.</td><td>Examples of previous students' work (6), student links in the LMS, and other useful exemplars.</td></tr>
<tr><td>30 min</td></tr>
</table>

Instructor Provide guidance about copyright and ethical use of others' materials. Make students aware that their podcasts may be shared publicly. *Students* Search for sound effects and other elements that may be usefully and legally incorporated into podcasts (7).	Links to Creative Commons (CC) and other free-to-use sound archives (8). 15 min
Optional	
Peer Feedback Set up mechanism for students to listen to other students' submitted podcasts and to provide peer feedback by answering questions in an online quiz (9).	
Extension Workshop (60 min) Optional technical workshop(s) on **recording**, to which students bring the devices they plan to use for recording, and where recording practices are modelled and discussed. *Resources:* Spare recording devices (10).	
Extension Workshop (60 min) Optional technical workshop(s) on **editing**, to which students bring the recorded material they need to edit, and where they are assisted to complete their editing. Resources: Computer(s) or mobile devices with editing software or apps preloaded (11).	

Notes

(1) A sample handout for the Podcast Assignment is provided as an online resource (ESM_4.pdf).

(2) The instructor should identify effective and ineffective exemplar podcasts and have them in reserve if needed as prompts for in-class discussion.

(3) In preparation for the in-class discussion, students should search online to find relevant short exemplar podcasts that appeal to them, uploading them into the LMS.

(4) Explicitly share the pedagogical rationale for the task with students and provide them with clear instructions, especially if they will be working on this task independently. We suggest a three-minute maximum length of the submitted podcast. Make it clear to students that creativity will be rewarded! Students are not always comfortable with this at the outset, since "creativity" is difficult to quantify. Explicitly recognize creativity in your assessment rubric to help alleviate their doubts. We also recommend providing a handout with links to free-to-use software, online tutorials, and other resources (see suggestions in WEBSITE LINKS).

(5) Storytelling is a powerful form of communication (see Chibana (2015) in WEBSITE LINKS). Use the tips presented to draw out class discussion about the value of stories for communication.

(6) After this assignment has been run once, you can share examples of previous students' work to provide inspiration, give an indication of what you are looking for, and demonstrate that diverse approaches are valid. Sample podcasts produced by our previous classes are provided as an online resource (ESM_1.mp3; ESM_2.mp3).

(7) Students may begin to explore sounds and sound effects in class and continue later. They could be invited to share links to relevant resource banks on an optional discussion board in the LMS. Clearly let students know that their podcasts may be shared (with their permission) and that they can use their podcasts on their own websites or in digital portfolios—this enhances student effort and copyright awareness. A template for a digital publication authorization form is provided as an online resource (ESM_5.pdf).

(8) Students must be advised about copyright issues and told that they can only include sounds that are in the public domain or under Creative Commons licenses, or which they have recorded themselves or have explicit written permission to reuse. Links to collections of CC-licensed audio can be added to the handout (see WEBSITE LINKS section).

(9) Peer feedback encourages students to create high-quality podcasts and improves their ability to constructively critique the work of others. We typically ask students to listen to a set number (2–3) of classmates' podcasts and provide feedback by answering questions in an online quiz in the unit's LMS. This comprises a small proportion of the final grade.

(10) Additional devices (smartphones, tablets, or digital audio recorders) should be on hand in case some students or groups do not have a recording device.

(11) We recommend using free versions of editing software (see WEBSITE LINKS section) so students can keep using them later and further develop their skills.

52.5 Top Tips for New Instructors

1. We have found that this creative podcasting assignment provides an active, student-centered, social constructivist learning experience. When students generate podcasts, we see evidence of improved learning outcomes as measured by

exam results. In contrast, when students listen to podcasts that others create, we see no measurable improvements in learning of the content material, consistent with a view that the active learning involved in creating the podcast is an important aspect of this assignment.
2. In our experience, students can feel overwhelmed if given a completely free choice of topics; many prefer a more limited topic choice guided by the instructor. Linking the topics to later assessments provides students with an added incentive to engage.
3. Encourage students to contextualize their content by providing relevant examples. For example, students in a chemistry class looking at acids and bases could create a story about reactions that might occur in a kitchen or other recognizable setting.
4. Setting the assignment as a group task means students are more likely to have access to the necessary technology (e.g., a smartphone for recording and a computer for editing). We have found groups of three are optimal. Providing an opportunity for students to assess their own and group members' contributions can mitigate student discontent about teamwork. The form we used for self and peer assessment is provided as an online resource (ESM_6.pdf)
5. It can be difficult to find times when all the group members can get together. It helps the team if meeting time is set aside during regular lab or tutorial periods. Discuss meeting plans with students in the class.
6. We run this assignment with an interval of about 4 weeks between task setting and podcast submission. An optional discussion board in the LMS helps students ask questions and get feedback from other students and the instructor.
7. The instructor need not be a communication specialist—there are plenty of online resources and tutorials for students to create podcasts. However, if the instructor (or a colleague) has recording and/or editing experience, optional tutorials can be organized for students who are unfamiliar with or intimidated by the technology.

Website Links

1. Online Resources provided by this chapter's authors:
   (a) ESM_1.mp3. Sample_chemistry_podcast_acid-base
   (b) ESM_2.mp3. Sample_chemistry_podcast_oxidation-reduction
   (c) ESM_3.pdf. Marking rubric used by authors of this chapter
   (d) ESM_4.pdf. Assignment handout used by authors of this chapter
   (e) ESM_5.pdf. Digital Podcast Publication Authorisation
   (f) ESM_6.pdf. Self and group assessment for use by students

A handout can be provided to students to facilitate their work on this assignment, with links to software and other resources such as those provided below.

2. Free recording and editing software:
   (a) Audacity is free, open-source recording and editing software that works across operating systems.

   (b) GarageBand for Macs and GarageBand for iOS is free recording and editing software for Apple devices.
3. Guides and tutorials on podcasting and recording:
   (a) Audacity (2021) *Tutorial - Your first recording*.
   (b) Audacity (2021) *Tutorial - Editing an existing audio file*.
   (c) Buzzsprout (2019) *How to edit a podcast in GarageBand* [Video].
   (d) Buzzsprout (2019) *How to start a podcast: Step-by-step guide* [Video].
   (e) The Podcast Host (2021) *Why record your podcast outdoors?*
   (f) Pegrum, M. (2021) Podcasting. *Digital learning*.
4. Guides on digital storytelling:
   (a) Chibana, N. (2015) 7 storytelling techniques used by the most inspiring TED presenters. *Visme*.
5. Freely reusable (Creative Commons-licensed) audio content:
   (a) CC Search: Audio.
6. Guides on copyright:
   (a) Electronic Frontier Foundation [USA] (n.d.). Teaching copyright: Handouts.
   (b) Smartcopying [Australia] (n.d.). Students and copyright.

References

Bartle, E., Longnecker, N., & Pegrum, M. (2011). Collaboration, contextualisation and communication using new media: Introducing podcasting into an undergraduate chemistry class. *IJISME, 19*(1), 16–28.

Pegrum, M., Bartle, E., & Longnecker, N. (2015). Can creative podcasting promote deep learning? *British Journal of Educational Technology, 46*(1), 142–152. https://doi.org/10.1111/bjet.12133

Further Reading/Exercises

Besser, E. D., Blackwell, L. E., & Saenz, M. (2021). Engaging students through educational podcasting: Three stories of implementation. *Technology, Knowledge and Learning*. https://doi.org/10.1007/s10758-021-09503-8

Gottschall, J. (2013). *The storytelling animal*. Houghton Mifflin Harcourt.

Haiken, M. (2020) *Podcasting for students: Tips and tools to drive creative expression*. International Society for Technology in Education.

Morris, T., & Tomasi, C. (2020). *Podcasting for dummies* (4th ed.). John Wiley.

Nancy Longnecker is a Professor of Science Communication at the University of Otago, New Zealand where she convenes the Science in Society study stream. She is a practicing and academic science communicator who has developed curriculum and taught science communication since 2002. Her recent work includes podcasting, interactive exhibitions, and cross-cultural communication.

Mark Pegrum is an Associate Professor in Digital Learning at The University of Western Australia, where he is the Deputy Head of School (International). In his teaching, he specializes in digital technologies in education, with a particular emphasis on mobile learning. His research focuses on mobile technologies, digital literacies, augmented reality, and mobile learning trails and games.

Emma Bartle is an Honorary Senior Lecturer at The University of Queensland. She has extensive teaching experience, using innovative teaching and learning practices to engage students. Her teaching connects concepts to the real world and explicitly links a science/research concept that may seem theoretical and abstract to show students how it is actually extremely relevant to their everyday life or professional practice.

A Step-by-Step Procedure for Developing and Testing an Effective Analogy

53

Marlit Hayslett

Genre - Distilling - Intent

53.1 Learning Outcomes

Abstract scientific and theoretical concepts can often be difficult to communicate to non-specialist audiences. How do you explain microfluidics, butadiene, or gene regulation to your neighbor? One option for communicating these complex concepts is to use something familiar to the audience, something they already know. Analogies are excellent tools for comparing complex ideas to everyday items. After completing this exercise, the learner will be able to apply a step-by-step technique for developing and testing an analogy.

53.2 Teaching Context

This activity is useful for students in science disciplines who struggle to explain concepts from their field in terms non-specialist audiences can understand. We often use analogies to explain unfamiliar concepts, but it is done intuitively. As an educator, I have developed a 5-step process for developing an analogy.

This activity is typically done over two class sessions. In the first session, students work together in groups to follow the steps and develop an analogy for a concept. Afterward, they work independently to develop an analogy for a concept specific to

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their research. Then they present this analogy to the class. Students at all levels and STEM disciplines can benefit from this exercise.

53.3 Overview of the Teaching Activity

The goal of this assignment is to equip learners with a step-by-step technique to conceptualize and test an analogy of a complex concept to an everyday item or process. The steps are explained here.

Step 1: Specify your audience. This is important because the way you would explain vaccines to a 5-year-old will differ from how you would explain it to parents of 5-year-olds.

Step 2: Brainstorm three to five characteristics of your complex (scientific or technical) concept. Does it grow rapidly or slowly? Is it resistant or susceptible to certain things? Does it change the way information is processed? Does it require human intervention?

Step 3: Choose an everyday item or process that shares some characteristics of your complex concept. Everyday items and processes can come from food, music, sports, travel, animals, and nature. Students often choose everyday items from cooking, transportation, and household because most people can relate to these activities. Cultural or social differences may alter this generalization (1).

Step 4: Use the analogy worksheet to make sure your analogy aligns with your complex concept on at least three levels (2, 3).

Step 5: Test your analogy on friends. You are testing to confirm that the explanation is clear. You are also listening to ensure that it is culturally appropriate. See (1) for an example.

53.4 Runsheet and Lesson Plan

This lesson plan introduces the concept with a group exercise and then gives students time to create and share analogies relevant to their own interest.

Instructor does…	Students do…	Resources
Introduce the process and the worksheet (1,4).	Ask questions	Analogy Worksheet 20 min
Explain the assignment and remain available for questions.	In groups of three or four, choose a topic from a list. Work together to follow Steps 1 through 4 and develop the analogy.	List of starter concepts (5) 20 min

Call on the groups to present their results and hence complete Step 5 (analogy testing).	Each group presents to the class. Peers react with a focus on whether the analogy retains alignment to the technical concept and has any cultural concerns.	 20 min
Extension (including Session 2) In an out-of-class assignment, students use the analogy worksheet to develop an individual analogy on a complex concept from their field. Present this analogy to the class in person or via video (6).		Analogy Worksheet 60 min
Extension In an out-of-class assignment, students exchange videos for a repeat of Step 5 and give peer feedback.		 30 min
Total duration in-class = 60 min + 90 min		

Notes

(1) When considering options for an everyday item or process, always start with the audience. What are they are likely to know? What are they not likely to know? As an example, in my class, a group was trying to explain the concept of a smart appliance. They focused on voice recognition technology, (i.e., Apple's Siri or Amazon's Alexa). One characteristic they identified was that the appliance obeys commands. The group (all Americans) compared it to the childhood game Simon Says in which the players have to do what the leader says in a certain a way. When the group tested their analogy on the class, it lost integrity because two members of the audience were from countries that do not play Simon Says.

(2) Alignment refers to the ways the complex concept and the everyday item or process map to each other, usually in terms of a shared characteristic. Here is a counter-example to explain. Let us say I visit with my elderly grandmother and she asks me what a *blog* is. Thinking about the steps in the analogy process, I have already completed Step 1 (my grandmother is the audience), and Step 2 (the blog is the complex concept). Now I need to think about an everyday item that she knows that can help me explain what a blog is. Knowing that she was an avid reader, I start with a book. "Well, Granny, it's a bit like a book, except it is not printed on paper. You read it on the computer." She replies that she has no desire to read something the length of a book on a computer. Let me try again. "Well, maybe a book wasn't exactly the best comparison. Blogs are usually quite short in length and can be on any subject. They are more like newspaper articles on the computer". Then she understands, and Step 3, choose an everyday item

(i.e. newspaper article), is complete. When I used a book as the analogy, it didn't align for Granny because she does not want to read a long book on a screen. However, the newspaper article worked better because the characteristics of length were more comparable. The alignment from blog to newspaper article has more integrity.

(3) The simplest analogy maps to one level. *Exercise is like medicine*. *The Internet is like a highway system. A blog is a like a book. Life is like a river.* While potentially poetic, this can be risky if the audience interprets the analogy other than how you intended to explain it. An analogy that maps to more than one level is more likely to be valuable when explaining a complex idea.

(4) The analogy worksheet includes an example along with a template for the student to ideate their own analogy. It is included as Appendix 54.1 to this chapter.

(5) If your students are all from the same discipline, you can have a list of four to six concepts from their field. However, if you have a multi-disciplinary cohort, you will need higher-level concepts. Concepts I use for this purpose include: smart appliance, drone, desalinization, autonomous vehicle, molecule, and chemotherapy.

(6) When deciding whether to require the students to do a live presentation or video, there are a few trade-offs to weigh. As a learning tool, I prefer videos for a few reasons. First, students can watch the videos repeatedly and focus on areas they want to improve. Second, as an evaluator, you can watch the video more than once to prepare feedback. Third, with videos you can schedule your evaluations, watching a few at a time to manage grading fatigue. For live/in-person presentations, the students go one right after another in a short amount of time. Of course, the final decision should align with the learning goals of the exercise.

53.5 Top Tips for New Instructors

1. One of the fun things about analogies is that there is no single correct answer. For my chemistry Ph.D. students, *catalyst* is the most popular complex concept to explain. Catalysts have been compared to a stapler, a lock and key, an energy drink, bread yeast, a blender, a ski lift, an unsharpened pencil, players in a basketball game, and spices in a stew.
2. Be ready to be surprised. Some students' analogies are quite innovative.
3. Emphasize that an "everyday item" should be familiar to everyone. I have had a couple of examples where students chose analogies that were as obscure to me as the technical concept.
4. Students often use sports analogies, but these can have important limitations. First, not everyone likes all sports or knows the rules of a particular game. Second, not all sports are played in every country. You can also apply this argument to other categories like cooking or travel. Regardless of the everyday item or process you choose, the bottom line is this: What will your audience know about it?

5. Learning how to develop analogies will be more impactful if you can introduce the concept with practice as described above, and then a few weeks later revisit it. One option for this would be to require the use of an analogy in a later presentation.

Additional Reading or Exercises

Appendix 53.1 Your Analogy Worksheet.

Marlit Hayslett coaches graduate students on how to share their research with non-specialist audiences. Her journey to science communication started with a career in science policy where she facilitated discussions between university researchers and elected officials. Marlit's research focuses on understanding how science is communicated to inform policy outcomes, particularly in international contexts. In 2022, Marlit transitioned from higher education to launch her own science communication coaching practice.

The Conclusion: How to End a Scientific Report in Style

54

Siew Mei Wu, Kooi Cheng Lee, and Eric Chun Yong Chan

Genre - Writing - Organising

54.1 Learning Outcomes

Sometimes students have the mistaken belief that the conclusion of a scientific report is just a perfunctory ending that repeats what was presented in the main sections of the report. However, impactful conclusions fulfill a rhetorical function. Besides giving a closing summary, the conclusion reflects the significance of what has been uncovered and how this is connected to a broader issue. At the very least, the conclusion of a scientific report should leave the reader with a new perspective of the research area and something to think about.

By the end of this lesson, students should be able to identify, analyze, and apply the rhetorical move analysis and key linguistic features pertinent to the conclusion section of scientific reports. In the Swales tradition (Swales & Feak, 2012), rhetorical analysis refers to the identification of language patterns in the stages within the conclusion and the functions of these stages. The activities in this chapter will enhance students' ability to articulate why the research, analyses, and findings matter.

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54.2 Teaching Context

This is a 90-minute lesson on writing a conclusion. We developed it as a blended module on writing the scientific genre for a Pharmacy Project report. The activity can be applied to the writing of conclusions in any scientific report. Ideally, in the preceding weeks, students would have learned the development of prior sections of a scientific report, namely Introduction, Method, Results, and Discussion. Students could be working on writing their own paper, or the teacher could provide a short scientific article with a missing conclusion so that the class can work toward a good conclusion to the article.

The lesson requires students to perform textual analyses to identify generic structures in given textual excerpts from professional- and learner-written sources. This involves the close reading of texts to analyze the stages within and the function (s) each stage plays. Although our examples and excerpts are pharmacy related, similar examples from other disciplines can be used.

54.3 Overview of Learning Activity

This lesson on conclusions teaches students to do the following: a) be aware of generic structures of conclusions, b) be able to identify and summarize major points in the discussion section, and c) use appropriate language to re-present main findings coherently.

This lesson begins with pre-work in which students discuss points raised in the tutorial notes on conclusions (Appendix 1) and complete quiz questions on conclusions (Appendix 2). Quiz questions with the highest numbers of incorrect answers are discussed as a class to clarify misunderstandings and to reinforce key points presented in the online lecture. Quiz questions that relate to textual analysis and deconstruction of how paragraphs move within texts help students recognize that sentences and paragraphs play different functions as the text develops. These key functions associated with the Conclusion section are as indicated below:

1. Restatement of objective(s)
2. Reflection of outcome(s)
3. Acknowledgment of limitation(s), if any
4. Connection to a wider context

After the students have learned how to recognize textual patterns by deconstructing a few provided conclusions, the students participate in an optional activity in which they identify the moves in sample article conclusions that they bring to class. Subsequently, the students construct their own conclusions to the article provided by the teacher, which has a missing a conclusion. Students could also build a conclusion for their own piece of writing at this stage.

54.4 Run Sheet and Lesson Plan

Instructor does …	Student does …	Resources
Set Quiz and Tutorial Notes as pre-work.	Engage with the materials before the class.	Quiz questions (1); tutorial notes (2).
With the whole class, go through quiz questions that are wrongly answered (1).	Clarify further areas of doubt arising from the tutorial notes (2).	As above 20 min
Explain forms and functions and provide examples using the conclusions taken from tutorial notes (4). Explain the four rhetorical moves.	In groups of four, identify these moves in the provided conclusions in pages 3-4 of the tutorial notes (3).	Example conclusions provided in the tutorial notes and in class. 30 min
Highlight language features in conclusion section outlined with relevant examples (5).	*Optional extension:* Examine example conclusions in their own disciplines to analyse the use of relevant language features.	*For optional extension:* Students provide sample articles in their discipline. 30 min
Together, engage in "Question and Answer" session to further clarify individual queries on conclusions.		10 min
Total duration in-class = 90 mins		

Notes

(1) There are usually common quiz questions that are incorrectly answered – your LMS will be able to collate the response data for you. These are the questions that are further discussed in class.

(2) Quiz questions and answers are shown in Appendix 2.

(3) The tutorial note activities (Appendix 1) and quiz will take students around 2 hours. Although they are set as pre-work, students will benefit from the discussion associated with tackling them again in-class.

(4) It is crucial for the instructor to unpack the rhetorical moves using excerpts such as the one below. We have also provided instructor notes below on how to unpack the moves. Matching the statements with the moves will help students realize that rhetorical function of each statement. Also, a conclusion may not have all four moves (1–4) present as move 3 is optional.

i). *In summary, we have assessed and characterized silibinin's various roles as an adjuvant in protecting against PZA- and INH-induced hepatotoxicity. ii) Our in vitro experiments suggest that silibinin may be safe and efficacious as a rescue adjuvant, both fundamental considerations in the use of any drug. iii) Further optimization of our in vitro model may also enhance silibinin's hepatoprotective effect in rescue, prophylaxis, and recovery. iv) Using this model, we have gleaned important mechanistic insights into its hepatoprotective effect and identified novel antioxidant targets in* *ameliorating HRZE-induced hepatotoxicity. v) Future directions will involve exploring the two main mechanisms by which silibinin may ameliorate hepatotoxicity; vi) the proof-of-concept demonstrated in this project will inform subsequent in vitro and in vivo preclinical studies. vii) Given the lack of alternative treatments in tuberculosis, the need to preserve our remaining antibiotics is paramount. viii) These high stakes necessitate future efforts to support our preliminary work, making silibinin more clinically relevant to patients and healthcare professionals alike*. (Goh et al., 2020)

In i), the restatement of outcome is reflected by the underlined words (what was assessed and characterized is restated).

In ii) the underlined words show reflection on the outcome - that sibilinin is safe and efficacious - using the tentative terms "suggest" and "may be"; the modal verbs point to the hedged manner in which the value and implications of the outcome is stated. This is consistent with scientific writing where value judgments are not often asserted in certainty.

In iii), elements 2 and 4 are both embedded within: *The optimization of the in vitro model is said to be able to enhance the drug's effect (reflection of value of outcome) and there is also a connection to the wider context as further optimization is needed before this value can be realized.* Again, the value of outcome is stated in tentative terms as in ii).

In iv), both elements 1 and 2 are reinforced as the more specific outcomes of attaining mechanistic insights and identifying antioxidant targets are restated and these outcomes are reflected as important and novel.

In v), element 4 is evident as future directions in investigating drug mechanisms are provided. This connection to the wider context is reinforced in vi) where the current proof-in-concept work will form the basis to further preclinical studies.

In vi and vii), the outcome of this study is implicitly valued as "necessary" as the connection to the wider world of a lack of alternative treatments in tuberculosis makes the preservation of remaining antibiotics paramount. The results will also inform future pre-clinical studies.

viii) ends the conclusion with both elements 2 and 4: the study outcome is assessed as "preliminary" but forming the basis for the wider context "future efforts" that will make the drug "more clinically relevant" to the medical community. Element 3 is not present in this excerpt.

(5) An analysis of words and phrases used in the conclusion may point to the values of the writer's scientific community. For instance, the highlighted words and phrases below show that being "first" to conduct the study or being able to "demonstrate" silibinin's safety are positive attributes of the study. A "proof-of-concept" is also valuable to this community. In this case, the demonstration of safety and efficacy of silibinin is the "most promising" aspect of the study, which indicates that safety and efficacy are fundamental considerations for the community. The conclusion ends on a very positive note as these two outcomes are reflected upon. The identification of mechanistic insights and or novel antioxidant targets are also important. Future work (connecting to the wider community) is assessed as necessary - this note underlines the value of the study because

it appeals to the community's understanding that society needs to preserve remaining antibiotics.

Our study is the first to assess *and characterise silibinin's various roles as an adjuvant in protecting against PZA- and INH-induced hepatotoxicity. Most promisingly, we demonstrated silibinin's safety and efficacy as a rescue adjuvant in vitro, both of which are fundamental considerations in the use of any drug. We also identified silibinin's potential utility as a rescue hepatoprotectant, shed important mechanistic insights on its hepatoprotective effect, and identified novel antioxidant targets in ameliorating ATT-induced hepatotoxicity. The proof-of-concept demonstrated in this project forms the ethical and scientific foundation to justify and inform subsequent in vivo preclinical studies and clinical trials. Given the lack of alternative treatments in tuberculosis, the need to preserve our remaining antibiotics is paramount. The high stakes involved necessitate future efforts to support our preliminary work in making silibinin clinically relevant to patients and healthcare professionals alike* (Goh et al., 2020).

54.5 Top Tips for New Instructors

1. Students must engage with the online materials and activities before class so they have a good knowledge of the basic conclusion structure.
2. This activity works very well when students deconstruct the generic structure in their particular sub-disciplinary journal articles.
3. Sufficient time and preparation must be given for students to read and understand the excerpts which may be "decontextualized" from the full articles.
4. Feel free to choose conclusions that come from papers your students will find relevant and interesting.
5. If students have reports that they are already working on, they should have some familiarity with the earlier sections of their report before they work on their conclusion.

Website Links

How to write a conclusion for a research paper. (https://www.indeed.com/career-advice/career-development/how-to-write-a-conclusion-for-a-research-paper). *Accessed 12 Jan 2022.*

Organising research papers: The conclusion. (https://library.sacredheart.edu/c.php?g=29803&p=185935). *Accessed 12 Jan 2022.*

Appendix 1: Tutorial Notes for Conclusion Activity

Tutorial Preparation	*Before your tutorial session, please go through the Tutorial Notes and do a short quiz.*

Learning Outcomes

At the end of the tutorial, you should be able to:

- Identify and demonstrate understanding of the roles of Conclusion section of research reports
- Analyze the rhetorical moves of Conclusion and apply them effectively in research reports

Introduction

The **Conclusion** of a paper is a **closing summary** of what the report is about. The key role of a Conclusion is to provide a reflection on **what has been uncovered** during the course of the study and to reflect on the significance of **what has been learned** (Craswell & Poore, 2012). It should show the readers why all the analysis and information matters.

Besides having a final say on the issues in the report, a Conclusion allows the writer to do the following:

- Demonstrate the importance of ideas presented through a synthesis of thoughts
- Consider broader issues, make new connections, and elaborate on the significance of the findings
- Propel the reader to a new view of the subject
- Make a good final impression
- End the paper on a positive note

(University of North Carolina at Chapel Hill, 2019)

In other words, a Conclusion gives the readers something to take away that will help them see things differently or appreciate the topic in new ways. It can suggest broader implications that will not only interest the readers, but also enrich their knowledge (Craswell & Poore, 2012), and leave them with something interesting to think about (University of North Carolina at Chapel Hill, 2019).

About the Conclusion Section

In most universities, undergraduate students, especially those in the last year of their programs, are required to document their research work in the form of a research report. The process of taking what you have done in the lab or from systematic review, and writing it for your academic colleagues is a highly structured activity that stretches and challenges the mind. Overall, a research paper should appeal to the academic community for whom you are writing and should cause the reader to want to know more about your research.

As an undergraduate student in your discipline, you have the advantage of being engaged in a niche area of research. As such, your research is current and will most likely be of interest to scholars in your community.

A typical research paper has the following main sections: introduction, methods, results, discussion, and conclusion. The other front and back matters of a research paper are the title, abstract, acknowledgments, and reference list. This structure is commonly adopted and accepted in the scientific fields. The research report starts with a general idea. The report then leads the reader to a discussion on a specific research area. It then ends with applicability to a bigger area. The last section, Conclusion, is the focus of this lesson.

The rhetorical moves of a Conclusion reflect its roles (see Fig. 54.1). It starts by reminding the reader of what is presented in the Introduction. For example, if a problem is described in the Introduction, that same problem can be revisited in the Conclusion to provide evidence that the report is helpful in creating a new understanding of the problem. The writer can also refer to the Introduction by using keywords or parallel concepts that were presented there.

Next is a synthesis and not a summary of the outcomes of the study. Ideas should not simply be repeated as they were in the earlier parts of the report. The writer must show how the points made, and the support and examples that were given, fit together.

In terms of limitations, if it is not already mentioned in the Discussion section, the writer should acknowledge the weaknesses and shortcomings in the design and/or conduct of the study.

Finally, in connecting to the wider context, the writer should propose a course of action, a solution to an issue, or pose questions for further study. This can redirect readers' thoughts and help them apply the information and ideas in the study to their own research context or to see the broader implications of the study.

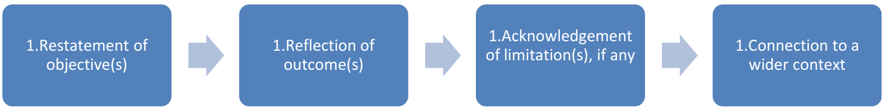

Fig. 54.1 Rhetorical moves of Conclusion (the University of North Carolina at Chapel Hill Writing Center,2019)

Linguistic Features of the Conclusion Section

In terms of linguistic features, the use of tense in the Conclusion section is primarily present where the writer's voice, position, and interpretation are prominent. This is followed by the use of the future tense in sharing what is ahead and some use of past when referring to the study that was done. As summarized by Swales and Feak (2012), Table 54.1 presents the frequency of use of the present tense and past tense in a research report.

Writing the Conclusion Section

Often, writing a Conclusion is not as easy as it first seems. Using the Question and Answer approach, below is a description of what is usually included in the Conclusion section.

1. **How long should the Conclusion be?**
   - One or two paragraphs comprising 1 sentence summarizing what the paper was about
   - Two to three sentences summarizing and synthesizing the key findings related to the thesis or objectives of the study
   - One sentence on limitations (if not in Discussion)
   - One to two sentences highlighting the significance and implications
   - One sentence on potential directions for further research
2. **Should the objective be referred to in a Conclusion?**
   - An effective Conclusion reiterates the issue or problem the hypothesis or objective(s) set out to solve. It is important to remind the readers what the hypothesis or objective(s) of the report are and to what extent they are addressed
3. **How far should the Conclusion reflect the Introduction?**
   - Referring to points made in the Introduction in the conclusion ties the paper together and provides readers with a sense of closure.
4. **How much summarizing should there be in a Conclusion?**
   - The conclusion can loosely follow the organization of your paper to parallel, but the focus should be on the paper's analysis rather than on the organization.
5. **Should newly found information be added to a Conclusion?**
   - Well-written conclusions do not bring in new information or analysis; instead, they sum up what is already contained in the paper.

   (Bahamani et al., 2017; Markowsky, 2010)

Table 54.1 Frequency of use of past tense and present tense

	Introduction	Methodology	Findings	Discussion	Conclusion
Present tense	high	low	low	high	high
Past tense	mid	high	high	mid	low

Task: Analysing a Conclusion Section

Consider Examples 1 to 4. How do the writers communicate the following information?

1. Restatement of objective(s)
2. Refection of outcome(s)
3. Acknowledgment of limitations, if any
4. Connection to wider context

Example 1

"According to this study, the use of educational models, such as a Precaution Adoption Process Model (PAPM) that most people are associated with the process of decision-making in higher education will be beneficial. Moreover, in the preparation, development and implementation of training programs, factors like increased perceived susceptibility, and perceived benefits should be dealt with and some facilities should be provided to facilitate or resolve the barriers of doing the Pap smear test as much as possible."

(Bahamani et al., 2016)

Example 2

"Community pharmacists perceived the NMS service as being of benefit to patients by providing advice and reassurance. Implementation of NMS was variable and pharmacists' perceptions of its feasibility and operationalisation were mixed. Some found the logistics of arranging and conducting the necessary follow-ups challenging, as were service targets. Patient awareness and understanding of NMS was reported to be low and there was a perceived need for publicity about the service. NMS appeared to have strengthened existing good relationships between pharmacists and GPs. Some pharmacists' concerns about possible overlap of NMS with GP and nurse input may have impacted on their motivation. Overall, our findings indicate that NMS provides an opportunity for patient benefit (patient interaction and medicines management) and the development of contemporary pharmacy practice."

(Lucas & Blenkinsopp, 2015)

Example 3

"In this review, we discussed several strategies for the engineering of RiPP pathways to produce artificial pep-tides bearing non-proteinogenic structures characteristic of peptidic natural products. In the RiPP pathways, the structures of the final products are defined by the primary sequences of the precursor genes. Moreover, only a small number of modifying enzymes are involved, and the enzymes function modularly. These features have greatly facilitated both in vivo and in vitro engineering of the pathways, leading to a wide variety of artificial derivatives of naturally occurring RiPPs. In principle, the engineering strategies introduced here can be interchangeably applied for other classes of RiPP enzymes/pathways. Post-biosynthetic chemical modification of RiPPs would be an alternative approach to further increase the structural variation of the products [48–50]. Given that new classes of RiPP enzymes have been frequently reported, and that genetic information of putative RiPP enzymes continues to arise, the array of molecules feasible by RiPP engineering will be further expanded. Some of the artificial RiPP derivatives exhibited elevated bioactivities or different selectivities as compared with their wild type RiPPs. Although these precedents have demonstrated the pharmaceutical relevance of RiPP ana-logs, the next important step in RiPP engineering is the development of novel RiPP derivatives with artificial bioactivities. In more recent reports [51 __,52 __,53 __], the integration of combinatorial lanthipeptide biosynthesis with in vitro selection or bacterial reverse two-hybrid screening methods have successfully obtained artificial ligands specific to certain target proteins. Such approaches, including other strategies under investigation in laboratories in this field, for constructing and screening vast RiPP libraries would lead to the creation of artificial bioactive peptides with non-proteinogenic structures in the near feature."

(Goto & Suga, 2018)

Example 4

"Our study is the first to assess and characterise silibinin's various roles as an adjuvant in protecting against PZA- and INH-induced hepatotoxicity. Most promisingly, we demonstrated silibinin's safety and efficacy as a rescue adjuvant *in vitro*, both of which are fundamental considerations in the use of any drug. We also identified silibinin's potential utility as a rescue hepatoprotectant, shed important mechanistic insights on its hepatoprotective effect, and identified novel antioxidant targets in ameliorating ATT-induced hepatotoxicity. The proof-of-concept demonstrated in this project forms the ethical and scientific foundation to justify and inform subsequent *in vivo* preclinical studies and clinical trials. Given the lack of alternative treatments in tuberculosis, the need to preserve our remaining antibiotics is paramount. The high stakes involved necessitate future efforts to support our preliminary work in making silibinin clinically relevant to patients and healthcare professionals alike."

(Goh, 2018)

In Summary

To recap, in drafting the Conclusion section, you should keep in mind that final remarks can leave the readers with a long-lasting impression of the report especially on the key point(s) that the writer intends to convey. Therefore, you should be careful in crafting this last section of your report.

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Appendix 2: Quiz for Conclusion Activity

Instructions

There are **6 questions** in this quiz. Choose the most appropriate answer among the options provided.

1. What does the Conclusion section of a scientific report do?
   i. It provides a recap of report, with reference to the objective(s).
   ii. It gives a closure to what has been discussed in relation to the topic.
   iii. It shares future direction(s) and in doing so connects to a wider context.
   iv. It propels the reader to have an enhanced understanding of the topic.

a. i, ii, and iii
b. i, ii and iv
c. ii, iii and iv
d. i, ii, iii and iv

2. The first rhetorical move of the Conclusion section is restatement of objective(s). It . . .
   i. reminds the reader the objective(s) of the report.
   ii. restates reason(s) of each objective of the report.
   iii. revisits issue(s) presented requiring investigation.
   iv. reiterates the importance of the research project.

a. i and ii
b. i and iii
c. ii and iii
d. iii and iv

3. The second rhetorical move of the Conclusion section is reflection of outcome(s). It . . .
   i. summarizes all the findings of the research project.
   ii. synthesizes outcomes of the research project.
   iii. is a repeat of important ideas mentioned in the report.
   iv. shows how key points, evidence, and support fit together.

a. i and ii
b. i and iv
c. ii and iii
d. iii and iv

4. In connecting to a wider context, the authors . . .
   i. remind the reader of the importance of the topic.
   ii. propose a course of action for the reader.
   iii. pose a question to the reader for further research.
   iv. direct the reader to certain direction(s).

a. i, ii, and iii
b. i, ii and iv
c. ii, iii and iv
d. i, ii, iii and iv

5. Following is the Conclusion section of a published article.
   "In summary, we have assessed and characterised silibinin's various roles as an adjuvant in protecting against PZA- and INH-induced hepatotoxicity. Our in vitro experiments suggest that silibinin may be safe and efficacious as a rescue adjuvant, both fundamental considerations in the use of any drug. Further optimisation of our in vitro model may also enhance silibinin's hepatoprotective effect in rescue, prophylaxis, and recovery. Using this model, we have gleaned important mechanistic insights into its hepatoprotective effect and identified novel antioxidant targets in ameliorating HRZE-induced hepatotoxicity. Future directions will involve exploring the two main mechanisms by which silibinin may ameliorate hepatotoxicity; the proof-of-concept demonstrated in this project will inform subsequent in vitro and in vivo preclinical studies. Given the lack of alternative treatments in tuberculosis, the need to preserve our remaining antibiotics is paramount. These high stakes necessitate future efforts to support our preliminary work, making silibinin more clinically relevant to patients and healthcare professionals alike." (Goh et al., 2020)

This excerpt of the Conclusion section. . .

i. restates objectives of the research.
ii. synthesizes outcomes of the research.
iii. acknowledges limitations of the research
iv. connects the reader to a wider context.

a. i, ii and iii
b. i, ii and iv
c. ii, iii and iv
d. i, ii, iii and iv

6. Following is the Conclusion section of a published article.
"In summary, we have assessed and characterised silibinin's various roles as an adjuvant in protecting against PZA- and INH-induced hepatotoxicity. Our in vitro experiments suggest that silibinin may be safe and efficacious as a rescue adjuvant, both fundamental considerations in the use of any drug. Further optimisation of our in vitro model may also enhance silibinin's hepatoprotective effect in rescue, prophylaxis, and recovery. Using this model, we have gleaned important mechanistic insights into its hepatoprotective effect and identified novel antioxidant targets in ameliorating HRZE-induced hepatotoxicity. Future directions will involve exploring the two main mechanisms by which silibinin may ameliorate hepatotoxicity; the proof-of-concept demonstrated in this project will inform subsequent in vitro and in vivo preclinical studies. Given the lack of alternative treatments in tuberculosis, the need to preserve our remaining antibiotics is paramount. These high stakes necessitate future efforts to support our preliminary work, making silibinin more clinically relevant to patients and healthcare professionals alike." (Goh et al., 2020)

What can one observe about the use of tenses in the Conclusion section? The frequency of use of present and future tenses . . .

a. demonstrates the importance results being synthesized.
b. is ungrammatical as the past tense should be used to state the outcomes.
c. propels the reader to think of future research.
d. suggests an encouraging tone to end the report.

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Part XI

Practice Joining the Conversation

Interactive Writing: Communicating with Your Audience Through Blogging

55

Michael Wheeler, Jen Martin, Catriona Nguyen-Robertson, and Linden Ashcroft

Conversation - Evaluation - Writing

55.1 Learning Outcomes

By completing this exercise, students will learn how to identify and evaluate the key features of a blog style of writing. They will learn how to implement these features into their own writing to engage a general audience in a science topic of their choice.

55.2 Teaching Context

Blogs are one of the primary ways in which science is communicated online. In many sectors, published blog articles are considered an output that can positively influence decisions around employability.

Blogs are a valuable medium of communication because they can use a combination of engaging writing, images, audio/video, hyperlinks, and discussion in the comments section. Taken together, this means that blogs do not only foster public *understanding* of science, but they can also take the next step to public *engagement* in science.

This activity is suitable for science students of any discipline from middle undergraduate level right through to graduate level. We have used it in both face-to-face and online teaching.

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S. Rowland, L. Kuchel (eds.), *Teaching Science Students to Communicate: A Practical Guide*, https://doi.org/10.1007/978-3-030-91628-2_55

55.3 Overview of the Teaching Activity

The lesson begins with a class discussion around the students' favorite science blogs. The instructor asks for a show of hands of those who enjoy reading science blogs, and if any particular websites come to mind.

The class discussion continues with a "think, pair, share" activity. The instructor asks the class to discuss in groups of three (or pairs for small classes) what makes a science blog engaging and informative. Each group shares these characteristics with the rest of the class to create a whiteboard list. This exercise is designed to help students identify the features of the blog genre, which are:

- An opening hook to grab the attention of the reader
- Conversational language that avoids jargon
- A narrative writing style as well as examples and analogies to help explain ideas
- Short paragraphs and subheadings
- Images and/or videos to enhance the reader's understanding of the topic
- Facts backed up with hyperlinked sources
- Dialogue with readers through responses to readers' comments

Next, students are provided with, and guided through, a handout of the rubric we use to evaluate blog posts submitted for assessment. It is useful to compare the features students identify as important elements of an engaging blog with those included in the rubric.

Finally, in groups, students pick an online science blog from the whiteboard list and read a post together using the rubric to evaluate its characteristics. The class finishes with a de-brief discussion on the task they have just completed.

This activity can stand on its own or serve as an introduction for an assessment task in which students write their own science blog post(s) in a way that satisfies the rubric they have become familiar with. Ideally, students publish their posts online where they can read each other's work (e.g., on a University WordPress website or in the course discussion board). The exercise can be enriched by asking students to make comments on their classmates' posts.

The assessment task description should include details on word count (we suggest 500–800 words), blog etiquette (being respectful and accurate), and correct use of copyright-free images (this information should be available from your institution's Copyright Office).

55.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Ask for a show of hands of those who enjoy reading online science blogs (1). List the students' blogs suggestions on a whiteboard. Discuss the role of blogging in science communication and the employability associated with being able to write about science in a conversational, accessible style (2).	Offer examples of science blogs they enjoy (3).	Whiteboard and marker. 7 min
Explain the "think, pair, share" activity. Use the whiteboard to record students' ideas about enjoyable blog characteristics. Facilitate a class discussion about the characteristics of engaging and informative blog writing.	Think about the characteristics of online blogs that they enjoy and discuss these in groups of two or three. Share with the class.	Whiteboard and marker 8 min
Provide students with a rubric that is used to evaluate the characteristics of a science blog. Talk through each characteristic and engage the students with a few focussed questions (4).	Consider what has already been discussed about the characteristics of blogs when answering focussed questions asked by the instructor.	Appendix 1: Rubric (see Resources) 10 min

Instructor does…	**Students do…**	**Resources**
Instruct students (in their same groups of two or three) to read through an online blog post from the whiteboard list, and use the rubric to evaluate the blog post (5,6). After reading, facilitate a de-brief discussion with students on how they evaluated the blogs.	In groups, read though the post and arrive at a consensus evaluation of the blog under each criterion in the rubric. After reading, share examples of their evaluations of different criteria.	Electronic device and internet connection to read the blog. 25 min
Extension You may wish to ask students to write their own blogs for assessment *Instructor:* Explain the blog assignment to students using your preferred task description (7). *Students:* Students write their own blog post(s) which are published online over a period of 2 – 10 weeks. During this _me students comment on each other's blogs (8).		A task description, Appendix 2: Blogging checklist, Appendix 1: Marking rubric (see Resources). 5 min in class Time outside class.
Total duration of introductory session = 55minutes.		

Notes

(1) If you are not sure your students are casual readers of blogs, you will need to set some blogs for them to read in advance of the exercise. We provide links below.
(2) We have also included some website links below that provide context on the important role blogs play in science communication and employability.
(3) In case students do not suggest any/many examples, the instructor should also have a few blogs in mind to add to the list (e.g. *The Conversation, Espresso Science, UniMelbScicomm; IFL Science; The Naked Scientists; Laelaps; CSIROscope).* Links for these are included in the resources below.
(4) For example, a focussed question might be, “What do you think is the purpose of an opening hook?” or “What are some examples of credible sources to use when hyperlinking key facts?”
(5) After the students have finished reading their posts, and begin discussing in groups of two or three how to evaluate the blog, walk around the class and join different groups briefly to comment (e.g. “That’s a good point you made about the tone of writing”, or “Have you thought whether those hyperlinked sources are credible?”).
(6) Depending on the students’ proficiency in providing feedback, suggest they at least discuss in groups how the post rates for each criterion and provide a score. If the students are more proficient, suggest they provide a score plus a brief written comment for each of the criteria.
(7) This assignment can be graded using the rubric the students have become familiar with, or it can be a non-graded exercise as students will receive peer feedback in the comments section.
(8) Make commenting on peers’ blogs a mandatory part of the assessment. We find this is necessary to get the desired outcomes of benchmarking, self-reflection, and fostering a community of enquiry.

55.5 Top Tips for New Instructors

1. Arrange the whiteboard and tables to facilitate discussions in groups of two or three. Ensure you can reach each student group when walking around the classroom so you can engage meaningfully in conversation with them.
2. When discussing the rubric, some points—such as including a clear narrative—can be difficult to articulate. We like to use the following suggestions for how students can include narrative: insert yourself or your own thoughts and experience into the blog; use characters; describe an event or scenario that had an outcome; or identify a problem or challenge that needs to be overcome (or was overcome).
3. It can be useful to discuss students’ ideas about credible sources for citing information. You might touch on the academic peer-review process or suggest students ask themselves “What does the author have to gain by telling this story?” when they read a source. This question may reveal conflicts of interest that can bring the validity of information into question.

4. When researching their own blogs posts, students (particularly undergraduate students) may not feel confident reading scientific papers, but you can encourage them to scan papers to "get the gist" and gloss over confusing jargon (or look up particular terms or ask for help). Students can also ask questions of experts on social media such as the authors of scientific papers.
5. Encourage students to share their blog posts on social media. Students invest more time and energy in their posts when they know they have a "real" audience. We highlight articles using our University of Melbourne Science Communication website and social media accounts (Twitter and Instagram—links included below). Students respond well to knowing we are proud to share their work. Sharing has helped some students land jobs at the end of their degrees through sparking conversations with organizations and/or individuals who read their blog posts.
6. Regular blogging fosters students' ability to write engaging, informative science stories for different audiences (i.e., other students, the public, non-specialists, etc.). We have found that by requiring students to write three to four blog posts over the course of 10 weeks, their writing improves enormously as they adopt plain language and avoid jargon.
7. We have found our students struggle to structure their blogs. Science students are likely familiar with the style adopted in scientific papers—starting broad and then narrowing down to the specific research outcomes. Science blogging, however, is inverted. Encourage students to start with the main outcomes and conclusions upfront, using catchy hooks before fleshing out the article with background information.

Website Links

Example blogs:

The Conversation. https://theconversation.com/au. Accessed 30 Jan 2021.
Espresso Science. https://espressoscience.com/. Accessed 30 Jan 2021.
UniMelbScicomm. https://blogs.unimelb.edu.au/science-communication/. Accessed 30 Jan 2021.
IFL Science. https://www.iflscience.com/. Accessed 30 Jan 2021.
The Naked Scientists. https://www.thenakedscientists.com/. Accessed 30 Jan 2021.
Laelaps. https://blogs.scientificamerican.com/laelaps/. Accessed 30 Jan 2021.
CSIROscope. https://blog.csiro.au/. Accessed 30 Jan 2021.

The role of blogging in science communication and employability:

Why science blogging still matters. https://www.nature.com/articles/d41586-018-01414-6. Accessed 30 Jan 2021.
How blogging can make you a better scientist. https://jenteottenburghs.wordpress.com/2020/08/21/the-benefits-of-science-blogging/. Accessed 30 Jan 2021.

Scientists should blog. https://conservationbytes.com/2014/05/27/scientists-should-blog/. Accessed 30 Jan 2021.
How science blogging can lead to a science writing career. https://www.nature.com/scitable/blog/scholarcast/how_science_blogging_can_lead/. Accessed 30 Jan 2021.
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A Q&A with The Atlantic's Ed Yong. https://blog.scienceborealis.ca/a-qa-with-the-atlantics-ed-yong/. Accessed 30 Jan 2021.

Lesson resources:

Appendix 55.1: Blog characteristics rubric
Appendix 55.2: Blogging checklist

University of Melbourne Science Communication social media accounts:

Twitter. https://twitter.com/unimelbscicomm?lang=en. Accessed 30 Jan 2021.
Instagram. https://www.instagram.com/unimelbscicomm/?hl=en. Accessed 30 Jan 2021.

Michael Wheeler has been part of the Science Communication teaching team at the University of Melbourne since 2019. He is passionate about all aspects of science communication from publishing scientific papers and presenting at conferences, to publishing blogs and podcasts. He represented The University of Western Australia at the Three-Minute Thesis Competition and worked with *The Naked Scientists* podcast in Cambridge.

Jen Martin worked as a field ecologist before founding the University of Melbourne's Science Communication Teaching Program which teaches scientists across all disciplines to be engaging and effective communicators. She also practices what she preaches: for 15 years she has been talking about science weekly on 3RRR radio, writes for a variety of publications and was named the 2019 Unsung Hero of Australian Science Communication.

Catriona Nguyen-Robertson teaches science communication and immunology at The University of Melbourne, and biology to school students from Years 5–12 at the Gene Technology Access Centre. She is a researcher at The Peter Doherty Institute for Infection and Immunity, and the Science Communications Officer for the Royal Society of Victoria and Convergence Science Network.

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Exercises to Develop Active Listening and Meaningful Conversations

56

Alexandra Anghelescu and Mihaela Sîrbu

Conversation - Listening - Arguing

56.1 Learning Outcomes

Many of us struggle to understand why a conversation or communication does not seem to be productive. This could be communication with a personal friend, a small group of colleagues, or an audience of a hundred non-experts. This exercise helps students reflect and start learning to:

- Hear, acknowledge and validate other speakers and the points they make
- Build on the arguments of others (instead of tearing them down)
- Build relations (bridges) before making arguments
- Actively listen to others in a conversation
- Understand the need to adapt to the audience instead of expecting the audience to adjust to them

At the end of this exercise, learners should have a more self-reflective way of addressing their communication challenges. The exercise helps them understand their default conversational modes (which may or may not be productive). It will lead them to ask “What am I not doing well?” and “How can I make this conversation work better?” rather than simply asking “Why aren’t people listening to me?”

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56.2 Teaching Context

We have used this sequence of exercises with groups of Ph.D. students as part of a "Public presentation of the scientific research results" mandatory course, but it can be used with any group of students, researchers, or people who need to create a dialogue with others.

The learning in this exercise is deeply experiential—it is about listening and conversational cooperation. The reflections between the games are key. For participants who are already aware of the need to acknowledge and build upon each other's contribution, the central "Yes, and..." game can be used as a warm-up for any kind of group activity.

56.3 Overview of the Teaching Activity

This exercise relies on two types of activity: playing games and reflecting on the outcome and how they made the students feel. The teacher is "coaching from the sides" and, depending on their experience, is more or less involved during the games. The games are explained briefly, as this exercise's objective is not to "get it right," even less so "to win," but to create an environment where participants can experiment with different styles of verbal interaction (Fig. 56.1).

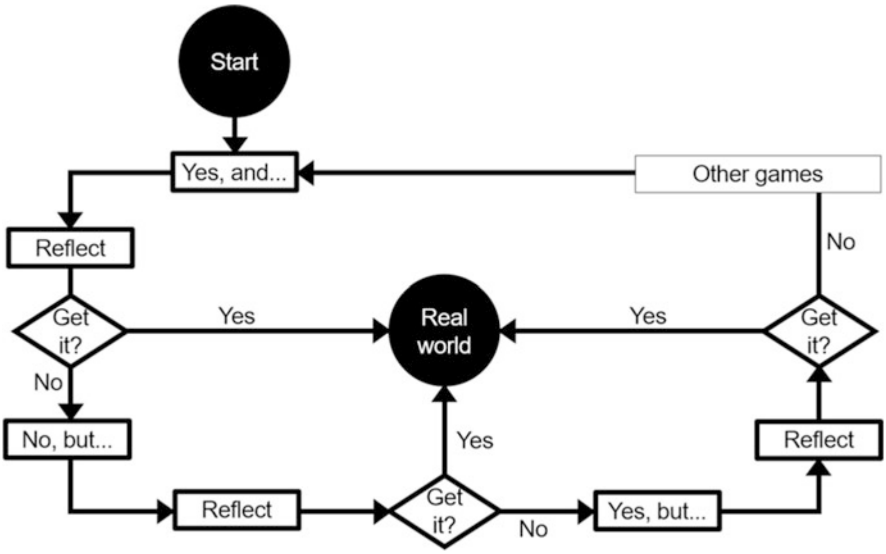

Fig. 56.1 Flow chart of activities

56.4 Runsheet and Lesson Plan

This activity requires space for everyone to sit in a circle on the floor or on chairs.

Part 1: The AND game
Instructor Explain the rules of the game. *We are going to play a game around the circle. One of us starts a story. Each person repeats what the person on their right has said and then continues the story, starting with the word "AND." After they add their part of the story, the the person on their left takes over. They and begin by repeating what the previous person has said and adds "AND", then adds their part of the story.* *Students* Listen and sit in a circle, with the teacher among them. **1 min**
Instructor Start the game with a simple phrase (a name and an action are good to have, i.e., "This morning, Michael was late leaving for school"). After 3-5 min and after each participant has contributed at least once, the instructor stops the game. *Students* Play the game. Contribute with their own ideas to the story. **3.5 min**
Instructor Ask for reflections, with some guiding questions: *What have we accomplished here? What is Michael doing? How does Michael seem? Is he going anywhere? Why is it so?* *How does this exercise make you feel? (1)* After the reflections, propose a new game ("No, but…) focusing on the different approach. *Students* Answer questions. Offer reflections about the story and their feelings and thoughts during the game (2). **2-3 min**
Part 2: The "No BUT" game
Instructor Starts a game of "No, but…" *Now we will try a different approach. We will start with "This morning, Michael was late leaving for school," as we are already invested in his adventures.* *In this game, however, each participant starts by refusing what the previous one has said ("No, Michael was not late leaving for school") and continues starting with the word" BUT."*

The game continues until each participant has contributed at least once. Coaches from the side for pace and compliance. *Students* Play the game according to the rules. **3-5 min**
Instructor Ask for reflections with similar guiding questions: *What is Michael doing this time? How is this different from last time? Was Michael going anywhere? Why is it so?* *How does this exercise make you feel? (3)* After the reflections, propose a new game ("Yes, but…), sharing some more insights into what the games aim to achieve. *Students* Answer questions, offer reflections about the story, their feelings and thoughts during the game. (4) **2-3 min**
Part 3: **The "Yes BUT" game**
Instructor Start a game of "Yes, but…". *Now we will try a different approach. We will start again with "This morning, Michael was late leaving for school" (as this exercise has become a personal challenge for us to get Michael to do something with his time!)* *This time each person accepts the previous participants' contribution and adjust it starting with the word "BUT." Then, you add your part of the story.* Keep it fast and to the point, looking for a natural breaking point after the first contribution by all those involved. *Students* Play the game according to the rules. **2.4 min**
Instructor Ask for reflections, with more probing questions: *What is Michael doing this time? Is he actually getting anywhere? Is this a story about Michael? If it is, how is it going?* Also, use some leading questions: *What made you reject the direction proposed by your colleague? How did it make you feel? How did having your idea rejected make you feel? Why do we try to one-up each other? (5).*

Conclude the three exercises by explaining how the "Yes, and…" exercise can lead to storytelling, while all other options ("No, but…", "Yes, but…") are disruptive and do not lead to cooperation or co-creation (of stories or anything else). Then propose a game of "Yes, and…" taking advantage of the things experienced. *Students* Answer questions, offer reflections about the story, their feelings and thoughts during the game (6) **5-6 min**
Part 4: Conclusion and reflection
Instructor Start a new game of "Yes, and…" with "This morning, Michael was late leaving for school" (we all hope he will have an exciting adventure this time). Coach from the side for pace and enthusiasm. Correct gently to keep everybody on track. Keep the ear open for the best place to end it. *Students* Play the game incorporating their insights from the previous stages. **5 min**
Instructor Ask for final reflections. This time ask more questions like: *How did you feel when your idea was accepted? How did you come up with the idea you used – did you prepare it in advance, or was it inspired by what you heard from your partner? Who is responsible for the success of this round?* Also, open the conversation to talk about relevance to real-life challenges: work, communication, difficult conversations (7). *Students* Answer questions, offer reflections about the experience, link to relevant real-life situations where this approach can be useful. **5 min**
Total duration in-class = *Minimum 30 min,* with up to 10 students, more with bigger groups; can be expanded with other similar games, mentioned below, to half a day.

Notes

(1) Usually, students are keen to show how original and interesting they are, and the game develops slowly, does not gel, starts in many different directions, and then loses steam. It is usually evident that students take the "AND" as a verbal connector, not as a sign of acceptance of what was previously said. As soon as the students mention the word "story," the instructor should use it as an opportunity to emphasize some fundamental rules (a story has a hero, the hero does things more than he/she feels things, the story should progress, with each action being a step on a ladder that culminates with a reward for the hero, etc.). The presence of story elements should be a good starting point for the next

exercises. If the word "story" is mentioned later (or not at all), the instructor should coach more on cooperating, on the need to accept what the partner has offered, in order to "build" something together.

(2) Students are slow to open up. The most vocal ones are probably the less aware of the missing point (there is no cooperation where people do not acknowledge each other's contribution), as they are focused more on how they performed. This is not a competition; the individual performance is not relevant; in fact, the more students want to stand out, the less well the exercise works. During the reflection time, the teacher should make sure that everybody has a chance to contribute, especially the quieter ones.

(3) The instructor draws attention to the conflict resulting from refusing each other's offer and the dissipation of focus, even if the group's energy is higher.

(4) Some students believe the previous game's apparent failure was due to the lack of good ideas (by others), so they have a chance to correct that by rejecting the previous player's idea and submitting their own. But the story goes nowhere and, after a couple of round-the-circle contributions, it becomes clear that the exercise is pointless. Sometimes, when they reflect on this subject, they actually articulate how refusing to build on each other's ideas creates an unpleasant sensation for all involved.

(5) The instructor draws attention to the fact that, because the wording ("BUT") allows for original and interesting contributions, it encourages the students to participate as individuals, not as team members. The questions should be more pointed, from inquiry about Michael (is he going somewhere?) to the feelings of the players whose ideas are being rejected, to the reasons students have for trying to one-up each other. This session could be the longest and deepest one, as here is where the teacher should help the emergence or emphasis on the idea that this could be a story, which is better when each player actually listens and accepts the offer made by the previous player. Also, this part of the exercise gives the teacher the opportunity to ask "Is this how we communicate with each other sometimes? We wait patiently for our partner to say his/her part, but we don't actually listen because we are already preparing the answer in our head" and "How many of us think we, personally, say" yes, but. . ." in our conversations?"

(6) This is when most students have an "Aha!" moment; they get the point of the exercise and start offering personal insights on how this makes them feel and how they see the error of the way they played these games previously.

(7) This is a congratulatory round, so the tone should be appropriately upbeat. During this last reflection, the teacher can get the students to talk about how it feels to be part of a group that accepts them and their ideas, how it feels to take an offer and, instead of judging or competing with it, take it to the next logical step, and see where it goes. Ask students to think about moments and places where this attitude could be relevant to their life. Also, depending on the time still available, it can be the beginning of a conversation about how this principle can be used in conversations, in communications in general, and in science communication instances in particular.

56.5 Top Tips for New Instructors

1. This game is not new to many people, as improvisation has been used in training scientists to communicate since Alda (2017) started hosting "American Scientific Frontiers" in 1990. We have not started this chapter by referring to his groundbreaking work because there is some reluctance among science professionals related to this subject, mainly because it seems to require some theatrical experience. While improv experience is not mandatory for this exercise, it is highly useful, so if there is an improv club near you, do take a class. On top of helping you with your communication, science communication, and science communication training skills, it is also fun and liberating.
2. If improv is not your scene, you can still use this exercise to help your students cooperate and communicate better. By shifting their perception from the scientist-as-communicator to the scientist-as-partner, you will give them more than just a few tips and tricks.
3. A few things to remember:
   - (i) Sit at the same level as your students or lower (Johnstone, 2003).
   - (ii) Coach from the sides (never ex-cathedra) (Spolin, 2009).
   - (iii) Ask questions, and only if they really struggle to articulate the ideas you are looking for, tell them yourself.
   - (iv) Ask what went well when things are going great. Deconstruct success just as you would failure.
   - (v) Keep it light. It is a game, not a competition.
   - (vi) Do not reward bad behavior (disruptive contributions, repetitive blocking, irrelevant comments, goofing around for easy laughs) by giving it your attention. Stop the behavior, then move everybody along.

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Hoopla! Beginners Improv Exercises. (https://www.hooplaimpro.com/improv-exercises-games-formats.html). *Accessed 4 Jan 2021*

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Active Listening: Learning Through Interviewing

57

Andrew Glester and Clare Wilkinson

Conversation - Listening - Working

57.1 Learning Outcomes

Active Listening is a concept borrowed from counseling and conflict resolution; it makes for better interviews and better interviewers. Students entering the workplace can effectively use Active Listening in many aspects of their work from science writing, podcast, and radio hosting to simply being better colleagues. It can also be a useful skill in research and evaluation.

This activity helps students to understand the importance of Active Listening as they begin to practice it in class and beyond. Students learn about interviewing techniques with Active Listening at the core and, after completing this activity, understand the key aspects of a journalistic interview. The students will learn about the key aspects of Active Listening: (i) paying attention (ii) showing that you are listening (iii) providing feedback (iv) deferring judgment and (v) responding appropriately.

57.2 Teaching Context

We have used this activity with third-year undergraduate students studying the module "Wildlife Film and Media" but variations of it are also used for students studying the MSc in Science Communication at UWE Bristol, particularly in the "Writing Science" and "Science on Air and on Screen" modules. As such, it is suitable for undergraduate and graduate-level classes. It is also appropriate when students are learning skills for work placements, group work, research, or any other

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activity when they need to listen to someone else and understand their ideas and perspective.

This approach to interviewing and conversations can be used in a variety of situations. We provide practical applications for students to apply their learning in our extra-curricular podcast and student magazine. You may also wish to extend your students' learning by linking this exercise to a co-curricular activity or assessment item that involves an interview.

57.3 Overview of the Teaching Activity

The activity gives students the opportunity to try interviewing and being interviewed. We start with examples of recorded interviews and a discussion about them in pairs before discussing the interviews as a whole class. Carefully chosen examples demonstrate interviewers who do not follow up on what has been said previously by the interviewee and the topic of listening always comes up in discussion. Other key aspects of a journalistic interview covered in the discussion include: (i) The importance of ascertaining information WWWWH (What, Where, When, Why, Who and How), (ii) good preparation, and (iii) listening to the interviewee.

The students are given the opportunity to try out interviewing for themselves. The students are divided into three groups (A) Interviewers (B) Interviewees and (C) Observers. The concept of Active Listening is introduced after the first round of interviews to give students some practical assistance with listening in the next round. The observer role adds another level of peer-to-peer learning to the session.

57.4 Runsheet and Lesson Plan

Instructor does…	**Students do…**	**Resources**
Provide exemplar interviews (1)	Watch interviews. Consider the interviewer. How do they interact with the interviewee?	Exemplar interviews 5 min
Initiate discussion about the interviewers' style and questions	Reflect individually and discuss the interviews in pairs. What did the interviewer(s) do well and do less well?	 5 min

Facilitate class discussion (2) Record reflections on white board (3) Describe the key aspects of a journalistic interview.	Share/discuss with peers (whole class) what worked and didn't work in the interviews and why. Share thoughts with the whole class.	Whiteboard or flipchart for facilitator 15 min
Set up Interview Session 1. Divide students into 3 groups. A, B, C. Highlight the importance of listening as the interviewer. Explain the role of Observer (4)	Group A (Interviewers) Group B (Interviewees) Group C (Observers) (students have these roles for Session 1, then will switch in Sessions 2 and 3)	5 min
Ask all students to prepare questions for when they are interviewing (5).	Groups A, B and C prepare questions for when they are the interviewer	5 min
Interview Session 1. 5 minutes for the interview (6). 5 minutes to discuss it amongst A, B and C.	A interviews B. C observes. C feeds back to A. They all discuss.	10 min
Facilitate Group Discussion Introduce the concept of Active Listening (7).	Discuss the experience of the interview from the three perspectives as a whole class.	10 min
Interview Session 2 5 minutes for the interview. 5 minutes discussing it as a 3.	Keep the same groups but now B interviews C. A observes.	10 min

Facilitate Group Discussion (8) Ask if and how the Active Listening helped?	Share thoughts with the whole class.	10 min
Interview Session 3 5 minutes for the interview. 5 minutes discussing it as a 3.	Keep the same groups but now C interviews A. B observes.	10 min
Wrap up the session with final thoughts and lessons from the session. Invite students to comment on how they can use active listening in their life (9).	Contribute specific ideas on how Active Listening can help them in their lives (study, relationships, work) (10).	5 min
Total duration in-class = Minimum 90 minutes but can be adapted depending on group size.		

Notes

(1) The example interviews should be short videos and illustrate specific points, most critically one which highlights the importance of listening. An overly talkative interviewer or one who does not listen to responses, leading to a stilted conversation can help with this. It can be useful to include an interview with, for example, a politician who avoids the question and ask the students to think of what questions they would follow up with to try and combat this. It is also reassuring to point out that scientists do not tend to be quite so tricky to extract the answers from in interviews. Only use interviews that are already in the public domain.

(2) The examples, if well-chosen, lead to engaged and engaging discussion but it helps to ask simple prompting questions (e.g., Who is your favorite/least favorite interviewer?). Follow up contributions by asking why they like, or do not like that interviewer.

(3) The aim here is to explore what the students feel makes for a better interviewer. Students' tastes will vary, but the ability to listen and respond accordingly is always highlighted by any group. This leads the discussion to the importance of listening and responding in interviews. For science journalism building a rapport with the interviewee is recommended. People are sometimes intimidated by the word "interview," so emphasizing that it is a conversation

or chat can help. We do not mention Active Listening at this point. We find it is good to allow them to try interviewing first and then introduce Active Listening to help them improve.

(4) The Observer's role is to watch the interview and feedback to the interviewer on what went well and where they could have improved. Ask them to listen to what the interviewee is saying closely and see whether the interviewer follows up on interesting points. You may also want to suggest they look for open and closed questions from the interviewer.

(5) The interview can be about anything but topics the students feel comfortable talking about works best. Good options include: the reason they are studying, music, pets, food or their favorite films.

(6) The interview should be a tight 5 minutes. Interviewers are often under time pressure and part of this exercise is to allow the students to begin to feel how it is to interview under some restrictions.

(7) Explain that Active Listening is borrowed from counseling and conflict resolution. Point out it is important for interviewers, but it is also useful in wider contexts of life including work, relationships, and study. Key steps are (i) Pay Attention, (ii) Show that you are listening, (iii) Provide Feedback, (iv) Defer Judgment, and (v) Respond Appropriately. Care should be taken to explain that these techniques take practice, particularly under the spotlight of interview situations or conflict.

(8) Here you may want to explain that in a live situation an interviewer might have a live feed from the Producer in their ear and have to be listening to that as well as doing the interview. You can also show a video example of somebody skilled at live interviews wearing an earpiece.

(9) Make the observation that, while Active Listening techniques can help in getting better interviews, it is also applicable and beneficial in interpersonal relationships and is definitely useful in the workplace.

(10) You may even want to ask your students to make an action plan for a situation in which they think Active Listening will improve something they are doing in their work, study, or personal life.

57.5 Top Tips for New Instructors

1. This can be a difficult exercise for students who are more introverted; using groups of three rather than having them perform in front of the whole class is helpful. It is worth emphasizing that students who are more introverted can often be very good listeners and interviewers. Equally, choosing a topic that students feel comfortable talking about can make people feel more at ease.
2. Use clips to demonstrate good and bad practice in interviews. The bad practice ones can add humor to the session as well as make the point efficiently.
3. Active Listening and interviewing both take practice. The session is set out to give each student three experiences of interviews and to learn from each other. Do

not expect students to have honed the skill in this session but do expect them to have learned what makes for a better interviewer.

Further Reading/Exercises

1. There are many videos on YouTube and websites about Active Listening, for example, this video gives some nice tips. Accessed 27th Jan 2021.
2. A variety of books are available on Active Listening, including Active Listening: Improve your Ability to Listen and Lead. Accessed 27th Jan 2021.
3. Podcasts are an excellent source to use when considering Active Listening. Ask the students to listen to podcast interviews and to practice listening as if they were the interviewer. Pause it occasionally and write down the questions they would ask next. Continue playing and consider how the interviewer did it differently. Were they listening and hearing something different? Were they apparently not listening and simply sticking to a script of questions?

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58 The Research Roleplay: Understanding the Process of Research and the Role of Research Stakeholders

Matthew Wood

Conversation - Investigating - Working

58.1 Learning Outcomes

Although science students are typically enthusiastic about science, many have not had an opportunity to consider the process of scientific research and knowledge-building as a human endeavour. Consequently, they may have an idealistic view of science as an impartial, analytical machine on a linear, pre-determined path towards an inevitable truth. Through this activity, students will recognize factors that influence both the direction of scientific enquiry and the quality of research output. They will also develop a more nuanced appreciation of how knowledge is created. As a result, they will have more fully formed ideas about the communication scientists do as they wrestle with ideas and research findings.

58.2 Teaching Context

I use this activity with undergraduate biology students in a science communication course as part of a broader strategy to (i) challenge students' notions of the infallibility or supremacy of science; (ii) encourage students to develop a more objective and contemplative view of science; and (iii) break down elitist attitudes which can hinder effective communication, particularly in public contexts. I also feel that science students can benefit more generally from imagining their future role as researchers or knowledge creators. This exercise helps them consider how they might contribute to knowledge creation, and where their ideas and motivations might come from.

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The activity is highly adaptable. For example, it could also be used to focus more specifically on the role of communications in research practice, on specific influences on the development of research questions, or even on the nature and quality of evidence. It is probably most impactful for undergraduate or masters students of any science disciple with limited exposure to real-world research contexts.

This activity was adapted from a lesson plan by Jean Beard (1999) focussing on scientific uncertainty and argumentation.

58.3 Overview of the Teaching Activity

Students are organized into small groups and thrust into a role-playing exercise in which they take on the role of researchers tasked with investigating a new "specimen." The students are free to ask their own questions and explore the topic as they wish, while "publishing" their findings on the board. Although the students have apparent freedom in their investigation, the activity incorporates motivational pressures designed to have inconspicuous but important influences on the way students work. These pressures include competition, collaboration, pressure to publish, research support, and available equipment. As far as possible the role-play tries to mimic actual pressures in the research world, albeit on a much smaller scale. Finally, through a guided discussion, students consider their motivations and actions and reflect on how even mundane aspects of the reality of research might impact the very knowledge that is produced.

58.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Divide students into groups of 4-6. Distribute 1 "specimen" to each group. Introduce the role play activity (1). Hear student observations without judgement or evaluation.	Self-organise into groups of 4-6. Verbally report one observation about "specimen".	"Specimen" puzzle boxes (2) 5 min
Explain the rules of the activity (3). Observe students. Encourage participation and remind students of activity rules where necessary.	Conduct "research" on the "specimen". Report findings on the board. First "publication" can name the "specimen".	Whiteboard divided into space for each group to report findings 20 min

After around 20 min, or when "publications" have started accumulating, announce research support in the form of "specialised equipment" (4). Hear funding applications from students and lend equipment to successful applicants.	Perform "research". Apply for research support. Publish findings.	"Specialised equipment" (5) 20 min
[Optional] If activity is progressing well, announce research support in the form of additional samples (6). Hear funding applications from students.	Perform "research". Apply for research support. Publish findings.	Additional "specimen" puzzle boxes 15 min
Halt activity. Briefly review students' collective findings. Encourage students to reflect on their actions and motives (7).	Review findings. Reflect on and discuss actions and motives.	15 min
Total duration in-class = minimum 75 min. Can be extended but a degree of time pressure works well in the activity. Enough time must be allowed for the reflection task, which could be moved to written homework activity or online discussion board if necessary.		

Notes

(1) Introduce the role play in the following fashion:
"Congratulations. You have graduated and are now working as researchers. Your group is your research team. Your team is fortunate to have a very rare specimen of something completely new and unknown to science. We know nothing about this new object and there are only [number of groups] specimens in the world. Please report one observation of your specimen."

(2) I use puzzle boxes handmade from sturdy cardboard microscope slide boxes (approx. 12 cm × 8 cm × 3 cm) with cardboard barriers, metal screw obstacles, and a marble inside, and taped firmly shut. There are two versions with different internal obstacles and different coloured tape. It is immediately obvious that there is something inside the boxes, though it is not clear what, or exactly how the interior is arranged. The activity is not contingent on the use of precisely these puzzle boxes. Any object with both clearly observable external features and hidden ambiguous features would work for this activity.

(3) There are three rules to the activity:
   (a) "Specimens" may not be broken or damaged (or opened).
   (b) "Publish" on the board when the team discovers something. Record the number of publications.
   (Publications can be simple abbreviated reports, using bullet points and diagrams, describing what students have found).
   (c) All researchers must research and publish repeatedly and continuously (or employment contracts will not be renewed).
   (d) Groups may collaborate and share publication count for any joint publications, but allow students to come up with this strategy on their own.

(4) Announce research support in the following fashion:
"Recently, [national research funder in your country] has noticed a cluster of new publications about this new object [use name given by students]. This seems to be an important, emerging area of science so [research funder] has decided to offer special assistance to researchers in this area. This assistance is in the form of access to the following specialized equipment: [introduce the equipment available]. If you would like to use this equipment, you should apply with a clear explanation of why you want to use it (research question and importance) how you are going to use it (method), and what you expect to discover (proposed outcome, answering the RQ). This assistance is only available to established researchers with a publication history of at least two papers."
   Equipment can be loaned to students for 5 min, after which time that group must give the equipment back and publish its findings.

(5) The "specialised equipment" can be any additional tools that students may not already have access to. I use rulers, weighing scales, magnets, magnifying glasses and so on (with more elaborate names of course). Including a mix of genuinely useful or versatile tools as well as some red herrings will allow for more interesting reflection when students consider how the availability of this equipment influenced their actions.

(6) Announce additional support in the following fashion:
"[National funder] has been impressed with research in the area of [specimen name] and at great expense to the tax-payer has discovered an additional [x number of] specimens. These are now available to researchers so if you would like to use these specimens please apply in the usual way."

(7) The reflection is guided by prompts from the instructor to explore where students' questions came from, why they did what they did, their strategies and reasons behind them, and how that influenced the collective findings of the class. This discussion clearly depends heavily on what happened during the activity, so flexibility is imperative.
   As an example of how this discussion might unfold, I find students typically focus on the inside of the "specimens," and few describe the exterior. Why is that? How would the collective knowledge on the board be different if more students had focussed on the exterior? Also, the availability of magnets tends to trigger a rush of investigations to test if the marble is metallic. How does the availability of research tools influence the questions researchers ask? Did the

two-paper requirement for research support encourage some 'quick and dirty' publications? Or did the hurdles of the application process prompt teams simply to give up on support and pursue different directions? How might these processes favour some researchers (and some types of research) over others?

Other points that could be brought up include: the influence of other groups' findings (publications); advantages or challenges of collaboration; role of communication in research processes; publication strategies (multiple, light publications or fewer, more significant publications); and so on. There is a lot of scope here to approach specific issues in your discipline, relevant cultural aspects, or any other considerations that are important for your students (e.g., most of my students are Japanese so we can discuss the specific challenges for non-native English speakers in the international world of research).

End by explicitly pointing out that science in reality is not a machine on a predetermined path to enlightenment, but rather a human endeavour subject to a myriad of very human influences, motivations, and choices which to a large extent determine its directions and outcomes. Invite students to compare this to how they viewed scientific research and knowledge building prior to the activity.

58.5 Top Tips for New Instructors

1. This activity works well at a brisk pace, so get started quickly and keep students busy. Preferably, they should be responding to circumstances (constraints and pressures) rather than considering their questions at leisure (how many researchers have *that* luxury?). Reflection, on the other hand, should allow plenty of time for examination and introspection.
2. Students' activities in the role-play should be entirely from their own volition. It is important not to give any hints, guidance or clues on what students should focus their attention on. If students feel uncomfortable or anxious because they do not know how they should proceed, that can be brought up and examined in the reflective discussion. It is easy to inadvertently influence students so care must be taken (e.g., at the opening stage do not ask "*what's inside?*" but rather *"tell me something about your specimen").*
3. Students will probably expect to be given the "correct" answer at the end of the activity. When they ask for the answer, I like to point the collective findings on the board and say *"This is your answer. Since you are the leading experts in this field no-one knows more about this topic than you do. If you are not satisfied, the only option is to do more research."*

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Website Links

An introduction to reflective thinking—what it is and why it is useful: University of Hull: Reflective writing. Introduction. (https://libguides.hull.ac.uk/reflectivewriting/reflection1). *Accessed 29 Jan 2021*.

Tips for integrating critical reflection into classes. University of Waterloo Centre for Teaching Excellence. Critical Reflection. (https://uwaterloo.ca/centre-for-teaching-excellence/teaching-resources/teaching-tips/planning-courses-and-assignments/course-design/critical-reflection). *Accessed 29 Jan 2021*.

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Embracing Communication Failures with Joy: The Role of Emotional Safety

59

Ralf Wetzel

Conversation - Engaging - Speaking

59.1 Learning Outcomes

Let us be honest: Making mistakes while communicating is the normality rather than the exception. However, we tend to run away from this inconvenient truth, with consequences. The fear of "messing up" makes us tense, inflexible and distant from the audience exactly when they want to find us relaxed, joyful and receptive. Making friends with our own imperfection helps us become authentic-as-self speakers and boosts our impact.

This session warmly invites the learner to the place of this fear and makes them familiar with the power this place unfolds once it is embraced. Students learn how to make themselves and any partner feel safe in their own hands so that communication can unfold in a truthful way.

59.2 Teaching Context

This session is a foundational part in courses like "building effective teams", "presentation skills", "agile leadership" and "innovation flow". It touches the very essence of how to take care of yourself and your partner's needs in any collaborative setting (including public speaking).

This generic module is suitable for all science disciplines and is applicable at undergraduate and graduate student levels.

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59.3 Overview of the Teaching Activity

The session consists of three parts. The first part helps students accept mistakes as they happen and let go of judgement. It builds a safety net for students to overcome their fear of failing in front of others. Students learn to allow themselves to "come and be as they are". This part is about liberating oneself from negative judgement and creating a space of emotional safety.

The second part is an exploration into what happens when failure is reframed from "doing something wrongly" to an appreciative expedition into something new. The key learning in this part is the concept of "yes, and!", a communication technique and skill coming from improvisation theatre that generates emotional safety between participants to explore something yet unknown.

The third part is about transferring the insights to a real presentation situation.

59.4 Runsheet and Lesson Plan

Instructor and students do…
Introduction (5 min)
Briefly introduce the learning objectives of the session: (i) Understand reasons of stiffness and paralysis in communicating in front of others (ii) Apply "yes, and!" to create emotional safety for oneself and the audience
Part 1: The Object Minus 1 Exercise (10 min)
The exercise consists of three steps: 1. Students walk through the room, point randomly at objects and call them loudly by their name 2. In the second round, students point at the first object and say "hmmmm", then point at the second object and call it by the name of the first object, so the objects and their names are shifted by -1. Whenever students lose focus or get out of track or are stuck, they need to shake their head and loudly say joyfully "AIAIAI!!" (pronounced eye-eye-eye) and start again. 3. In round three, students point to two objects and name them "hmmmm". The third object the student encounters gets the name of the first. Again, say loudly "AIAIAI!" when losing focus. 4. Round four is about pointing at any object and calling it anything except its correct name. Use "AIAIAI!" when getting stuck or blank.

Instructor side-coaching notes

- Take part in the exercise yourself passionately and own it. Do the “AIAIAI!” yourself, show imperfect behaviour, and allow yourself to laugh about it. That gives licence to the students to follow.
- Encourage and reinforce students when you hear them saying “AIAIAI!”
- Follow your own intuition when to shift between the different steps of the exercise, don’t overdo or underdo each step. Listen how many participants follow the exercise and how often you hear the “AIAIAI!”; that gives an indication of when to move on.

Debrief

- Ask students how they feel after the exercise. Typically, students talk about feeling confused, but lighter and more awake.
- Ask when they had the most fun in the exercise. Typical response: when participants have failed or they noticed someone else failing.
- Ask how students were feeling when they heard someone else messing up and how they felt when it happened to themselves. Typically, students talk about gloating when hearing others fail and about embarrassment when they fail. Hearing and making these honest responses helps students share emotions and guilt and lose their fear of making mistakes (1).

Part 2: Building Playfulness with an Audience Partner (35 min)

The following exercise helps to truthfully connect with any audience, it is called “One-word-at-a-time-story”.

1. Ask the students to provide one random object that is here in the room. Pick one of them to use as the subject for the story (e.g., an apple). Announce to the students “Let’s use an apple!”

2. Ask the students, to form pairs and to develop a story about an apple. In the pairs, the one with the longer hair/taller (choose a differentiating feature) is person A, the other is person B. Person A starts the exercise with one word only, then it’s the other’s turn. They build the story one word at a time.

Starting with “Once upon a time …” (that brings you quickly into fairy tale land, where everything is possible) demonstrate with one person to show how it works.

For example:

(A): Once (B): upon (A): a (B): time (A): there (B): was (A): Adam

(B): who (A): wanted (B): to (A): become (B): smart

Encourage the students “Now you go and do it!”

Resource *Improv Comedy: Game - One Word at a Time* - YouTube (accessed February 2021)

This exercise is similar to the one described in Anghelescu & Mihaela Sîrbu, in this volume, but not focussing on group processes.

Instructor side coaching notes - Walk around and collect quotes of flow and laughter as much as moments of being stuck, boredom, frustration, withdrawal in terms of body language, eye-contact, voice pitch. - After about 3 min, ask students to come back and tell 2-3 resulting stories. Be appreciative of any story being presented and be genuinely interested in any outcome. Point out when anyone starts judging the stories.
Debrief - Ask "What did you do when there were pauses or no progress in the story development?" Record students' observations on a white board. Collect concrete behaviours (e.g., thinking, evaluating, adjusting). This question identifies when students were STUCK (2). - Ask "What did you do when they story developed fast - when there was laughter, joy and curiosity?" Note students' observations on a white board. Collect concrete behaviours (e.g., eye contact, smiling, accepting, building on the other's words). This helps identify when student have been in FLOW (3). - Discuss the difference between being STUCK (2) and FLOW (3).
Iterate - Ask students to redo the exercise in newly shuffled pairs, only focussing on the flow-behaviour. Let them do the exercise two more times (three in total, each new round again for about 3 min) so that they really feel the difference between the first and the third.
Debrief the whole exercise - Ask students "How do they feel now? What's the difference to the feelings you had after the first round?" Typical answers are "it's more fun, we went wilder, we really had a connection!" - Ask "What did you do to achieve that?" and bring any responses back to the notion of how it felt to be accepted, to see that the other was really doing something with whatever one was providing. All of these behaviours of accepting and building upon the other turns the fear of failing into the curiosity to explore something unexpected. It provides the essential experience that there is no mistake but instead a partner that is empathetically accepting any contribution of the other. - Present the PLAY!-model of improvisation (see Tint et al. (2015: 85) & Appendix 1) and explain how to create a truthful connection between communicator & audience.
Part 3: Practice Your Presentation Playfully (30 min)

This section is meant to practice communication/presentations according to the PLAY!-model. The facilitator reminds the students that any presentation is similar to a one-word-at-a-time story rather than a one way-transmission of information. It’s a constant exchange and turn-taking between speaker and audience, verbally and non-verbally. Both audience and speaker create one experience by constantly listening to and building upon each other. Split students in groups of 3 students. They take turns in giving a three-minute-part of a real presentation to each other and then getting seven minutes of feedback. Instruct all presenters to pay attention to the elements of the PLAY!-model (4). Encourage listeners to act naturally but empathetically, showing any signs of how they truly would respond to the presenter, while staying empathetic with the presenter. Each presentation ends with a debrief by the listeners, which is empathetic, rewarding for the positive impact the presentation had and addressing wishes, where the presenter might develop.
Part 4: Final Debrief (10 min)
Ask students during to share: - when they were disconnected from their partners and feeling at risk and the related emotions. - when they were connected to and emotionally safe with the partners and the related emotions. - Core insights from the session. Harvest and emphasize actions that helped make the speakers and their audience feel safe.
Total duration in-class = 90 min

Notes

(1) This is the state of mind we want to achieve: liberating ourselves from the fear of making mistakes loosens our mind and body, we become much more explorative, present in the moment and able to find the surprising details any situation holds for us. The fear of being judged makes us tight and conservative in our behaviour. Communicating/presenting is generally a mirror game. The audience copies the mental and emotional state of the presenter. If the presenter is tight and conservative, the audience will be too.
Presenters need to give themselves (and their audience) permission to let go of their fear. The first step involves getting oneself into a light, self-embracing,

explorative mood. Accordingly, this exercise can be used as a warm-up that anyone can play before a communication event.

(2) When students are STUCK they realize that the contribution coming from the other is not in line with their own ideas and plans. At this point, they usually go into thinking mode, they plan the story ahead, and they try to control the outcome. When it does not go their way, they can get frustrated. Being stuck results from judgement, an ego-centric position and a reluctance to accept what has been provided by the partner.

(3) When students are in FLOW, they focus on each other (and not on their own thinking/judging) and are empathetic to each other. They also curiously accept what they receive from the other and build on it based on their own intuition. Being in a flow results from genuinely being with the partner, empathetically starting from and supporting the other. This behaviour provides emotional and psychological safety to the other, which allows both partners to relax and get over the anxiety that they may be judged.

    FLOW behaviour shows a genuine interest to what the partner has to offer, and it gives the feeling that the partner is a source of inspiration and joy rather than refusal, judgement and criticism. As a speaker/communicator, this is what we want to achieve. We want to make our partner and audience feel safe in our hands, we want them to feel that we are interested in them and that we want to start from their point of view. Once they feel that we are willing to accept and build our contribution and story from where *they* are right now, they will be excited to make *us* comfortable and will be willing to take us as a source of inspiration.

(4) They need to read the room in terms of non-verbal signs about the energy in the room (Presence). They should constantly accept and build upon any feedback they receive from the audience during their talk like smiles, laughter, boredom, frustration etc. (Yes-anding). They should especially respond to negative signs (boredom, frustration, tiredness) and should alter something during their talk in these situations (Adaptability). Students are encouraged to go to where the fear is (Leaping into), meaning they are recommended to openly address the students when they feel they lose or have lost them.

59.5 Top Tips for New Instructors

It is essential that new instructors have experienced the exercises beforehand. You may like to join some beginner's improv classes to learn and practice.

The one-word-at-a-time exercise requires some practice. It can be a challenge to let go of your own ideas and plans; try some sessions with peers and friends before using the exercise in teaching. Do not feel, however, that you need to be a perfect story developer. Imperfection is the core subject of the session, and it is helpful for the facilitator to display imperfection too! Be as you are and give the students permission to be their authentic selves as well.

Appendix 1: The PLAY!-Model of Improvisation

The PLAY!-model of improvisation stems from Raymond Van Driel, an Applied Improvisor from The Netherlands (Tint et al., 2015). It consists of 5 letters in the PLAY! Acronym. They stand for

(P)resence: be with your partner, notice everything and be willing to accept wherever your partner is. The more you notice, the more you can play with.

(L)eaping into: Take a risk and offer your own truth, share something truthful about yourself. Don't pretend anything, come and be as you are. Take vulnerability as your strength, rather than as a weakness.

(A)daptability: Allow yourself to get altered by your partner, go where the relevance is for your partner rather than for yourself. Work with everything you receive from your partner, don't block it by your own view.

Say (Y)es, and ...!: Accept what you receive from your partner, search for the inspiration it brings to you and build upon it. Make your partner look good, no matter what.

(I)mpact: If you follow those 4 orientations, you will become bold and impactful in your conversation and presentation.

Reference

Tint, B., McWaters, V., & Van Driel, R. (2015). Games for learning and dialogue in humanitarian logistics. Applied improvisation training for disaster readiness and response. *Journal of Humanitarian Logistics and Supply Chain Management, 5*(1), 73–94.

Further Reading/Exercises

Jackson, P. Z. (2000). *58 ½ ways to improvise in training: Improvisation Games and activities for workshops, courses and team meetings*. Gower.

Wetzel, R., & Tint, B. (2019). Using applied improvisation for organizational learning in the red cross red crescent climate centre. In E. Antonacopoulou & S. S. Taylor (Eds.), *The impact of learning: A relational approach to the difference art-based methods make* (pp. 245–263). Routledge.

Website Link

More useful improv exercises for own needs can be found and adapted here: www.improwiki.org/en. *Accessed 13 Dec, 2022.*

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Part XII

Practice Arguing and Organising

How to Construct Evidence-Based Arguments in Science

60

Helen Drury and Meloni Muir

Arguing - Genre - Writing

60.1 Learning Outcomes

Students studying science, especially in early undergraduate years, are building their knowledge in the discipline area. This often gives them a mistaken impression that science is about 'getting the right answer'. This activity will raise student awareness that science is contestable and this is reflected in the way scientists write.

In this activity, students learn to identify structure and language features of factual and persuasive or argumentative writing in the sections of a laboratory or technical report. Students learn about resources they can use for persuasive writing and how to deploy them in developing an evidence-based argument in the Discussion section of a report.

60.2 Teaching Context

These activities address a key genre in science communication—the laboratory report. This text type requires students to distinguish between factual and persuasive writing and recognise that factual writing can provide the basis for persuasive writing in the form of argument, evaluation and/or interpretation. The activities aim to make explicit the structures and language that can be used to develop persuasive writing, in particular in the Discussion section. It can be used in the early undergraduate years across science disciplines.

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60.3 Overview of the Teaching Activity

In the first activity, students examine example extracts from Results and Discussion sections of students' reports. We provide examples from a report in the Biological Sciences (Table 60.1). Students work to identify which section of the report an extract is from and provide reasons for their choices. We gather students' reasons in Table 60.2.

We then introduce the concept of the whole of a report as a persuasive text or genre, an argument and point out that the purely factual sections (Methods and Results) lead up to and provide evidence for the argument in the Discussion (Fig. 60.1).

In the second activity, students work together to reorder a jumbled Discussion section on the same topic (Table 60.3). During this activity, students need to develop reasons for their ordering of the stages as well as a label for the function of each stage. We reword students' function labels and present the typical stages of a Discussion section (Fig. 60.2) and show how these stages are ordered in a logical way to develop the argument.

In extension activities (see Appendix), the instructor works with students to further explore the structure of other sections of a typical report as well as the role of evidence and language features in developing the argument in the Discussion.

60.4 Runsheet and Lesson Plan 60Ł

It is assumed that the instructor has a whiteboard and/or a computer with projector for all stages of this exercise.

Instructor and students do…
Activity 1: Examining the research report as an argument and understanding the purpose of the Results and Discussion in that argument (30 min) *Instructor:* Ask students to form pairs. Provide example extracts from Results and Discussion sections of a report (Table 60.1). Ask students to identify which extracts are from which section and justify their choices to each other. Facilitate whole-class discussion and summarise students' reasons for choosing a Results section versus a Discussion section in terms of typical features of factual versus persuasive writing in these extracts (Table 60.2). After this discussion, use Fig. 60.1 to introduce the concept of the report as argument with the Discussion as the main section for the argument. *Students:* Read extracts and identify Results and Discussion pieces. Discuss the reasons for their choices. As a class, discuss ideas. *Resources:* Results and Discussion extracts (max. 6) from a single report (Table 60.1 or similar); Figure 60.1

Activity 2: Unjumbling a scrambled discussion (30 min) *Instructor:* Provide jumbled segments from the Discussion section of a laboratory report (Table 60.3). Ask students to work in pairs to correctly identify and order the jumbled segments into logical stages and to give each a name(s) or label(s) according to the function(s) it performs in developing the argument in the Discussion. Facilitate discussion and 'reword' students' labels for each stage into those typically used to describe stages in a Discussion. Then, show students Figure 60.2 *Students:* Read segments and identify the order of the stages. Name/label each stage and discuss the reasons for their choices. As a class, discuss ideas. *Resources:* Extracts from a Discussion (Table 60.3 or similar); Fig. 60.2
Total duration in-class = 60 minutes (see Appendix 1 for extension activities)

Notes

Table 60.1 Extracts from the Results and Discussion sections of a student laboratory report in the Biological Sciences on establishing the quality of a potential supply of drinking water (with answers)

Extract from student results and discussion sections	Report section
Extract 1. Using a two tailed *t*-test it was found that the mean (± S.E.) density of bacteria in the rainwater tank was not significantly different from the standard of 100 CFUs/mL (t = 1.35; *d.f.* = 7; P>0.05).	Results
Extract 2. However, in one replicate, the final density of 4.6 million bacteria was found to be far greater than all the other replicate values and may be the result of an error in calculation.	Discussion
Extract 3. Table 1. The mean density and range of bacteria in water collected from a rainwater tank and sterilised water (CFUs/mL) (this Extract would also include the Table).	Results
Extract 4. The high density of bacteria across the six replicates varied considerably. Such a large variation could be due to chance or sampling errors.	Discussion
Extract 5. The results show that the water quality of the rainwater tank, a potential supply of drinking water, is not fit for human consumption (NHMRC, 1996). This is due to the high number of colony forming units (CFUs) in the sample of water tested. The mean CFU count of 3502/mL (Table 1) was considerably higher.	Discussion
Extract 6. The results in Table 1 show that the mean final density of bacteria in the rainwater tank was 3475 colony forming units (CFUs) per mL. In comparison, the mean density of bacteria in the control water was 0.5 CFUs per mL.	Results

Table 60.2 Typical writing features in the Results and Discussion extracts from the water quality report

Results : Features of factual writing	Discussion: Features of persuasive writing
Table caption stating all the components in the table Statistical significance stated (… **not significantly different** …)	General statement interpreting the results and linking them to the aim of the experiment and evidence from the literature
Reference to results in table and summary and comparison of results (**The results in Table 1** … **higher** than) Summary of main results based on findings (the **mean number** … **considerably higher**) Summary and description of main results in the past tense (… **was** considerably higher …)	(… not fit for human consumption (NHMRC, 1996)). General statement using the present tense (… **is** not fit …) Evaluative comment on result (… was **considerably** higher.) Providing evidence for the interpretation of the results (This is **due to** …) Providing a possible explanation for an unexpected result using tentative language (**could be** due to chance …)

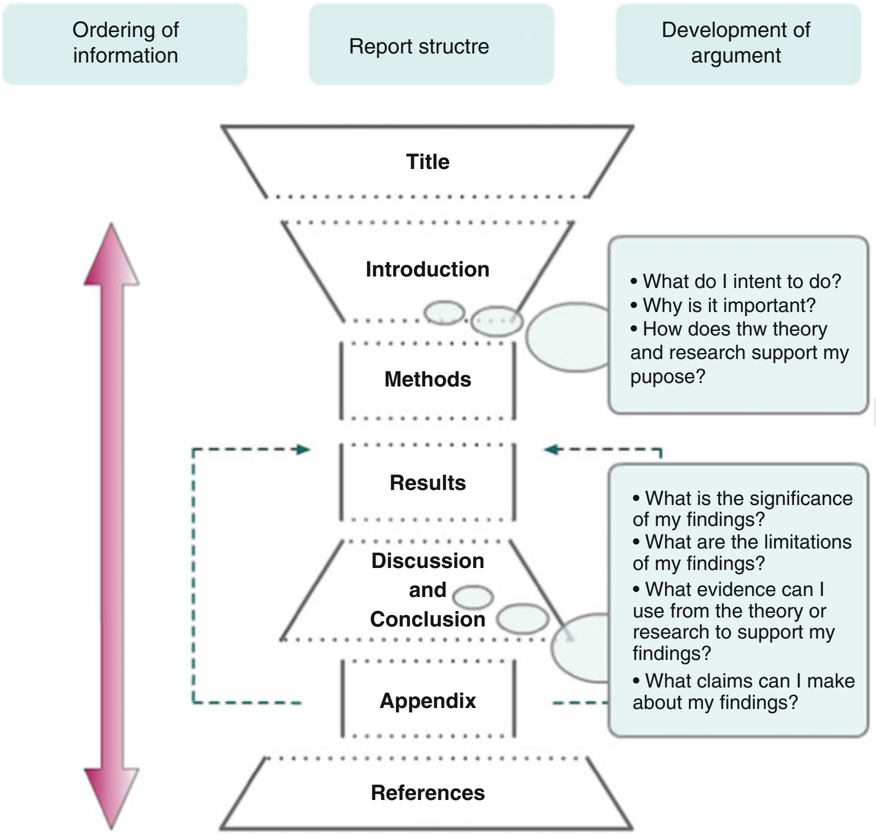

Fig. 60.1 The laboratory report as an argument (from the WRiSE website, Drury & Jones, 2009)

Table 60.3 Jumbled stages of Discussion section from student water quality report (with answers)

Jumbled extracts	**Order of extracts** ***and their function***
Extract 1. Despite this, the water is not recommended for human consumption, as all CFU values exceeded the recommended standard and there was a large amount of variation among the samples (NHMRC, 1996).	2. Relate to aim *Explain results* *Refer to research*
Extract 2. The experiment produced unexpected control results that showed the presence of bacterial colonies in supposedly sterile water. The controls serve to identify the number of bacteria that arise during the experiment and can indicate poor technique. The variability in the range of the eight replicates was consistent with poor technique.	3. Explain results *Discuss limitations*
Extract 3. The statistical analysis of the results show that the density of bacteria in the domestic rainwater tank was not significantly different from the current recommended standard for safe drinking water of 100CFUs per mL or less (School of Biological Sciences, 2000).	1. Relate to aim *Explain results* *Refer to research*
Extract 4. However, some of the variability is accounted for by the uneven distribution of bacteria through the samples with aggregations occurring particularly in the sludge.	4. Explain results
Extract 5. Since the level of bacteria in the rainwater tank is above the recommended standards, an adequate treatment technique utilizing coagulation, settling and filtration along with appropriate disinfection is essential to improve the water quality (NHMRC, 1996).	6. Explain significance
Extract 6. Greater accuracy in the counting of CFUs with more replicates and only one group performing the experiment is required in future experiments. In addition, the rainwater samples should be mixed thoroughly, with an improvement in sterilisation techniques.	5. Discuss improvements
Extract 7. Although the results indicate that the rainwater is not fit for human consumption, further tests are required to determine the extent and sources of contamination so that appropriate treatments can be carried out.	7. Conclude

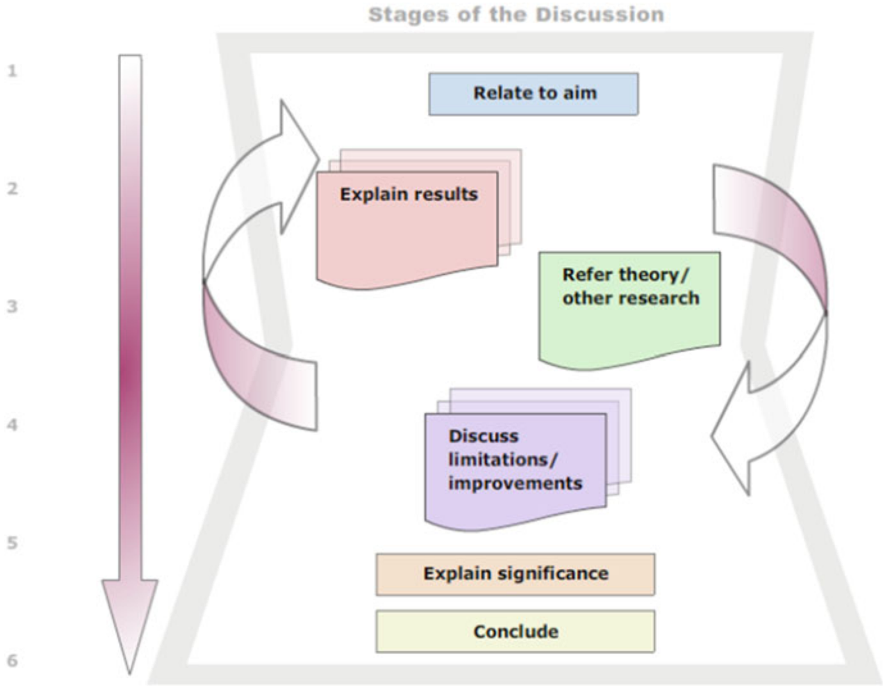

Fig. 60.2 Stages of a typical laboratory report Discussion section. The hourglass shape illustrates the movement of writing from general to specific to general to conclude the Discussion section (WRiSE website, Drury & Jones, 2009)

60.5 Top Tips for New Instructors

1. Collect examples of **student** writing of laboratory reports (with permission) for these activities. This makes the activities more realistic for students and can lead to a discussion about the strengths and weaknesses in the writing and how the writing could be improved.
2. Emphasise that stages in the presentation of information in a Discussion section are typical stages (Fig. 60.2). Students must adapt these to the specific content of the laboratory report they are writing (e.g. combined and repeated stages of Relate to aim and Explain Results).

Appendix

A.1 Extension Activities

In the first extension activity, after students have distinguished between extracts from Results and Discussion sections, they order jumbled extracts from the whole of an example report on the same topic (water quality report). They identify the sections the excerpts come from and discuss the reasons for their choices (Table 60.4). The instructor gathers students' answers and their reasoning into a table and summarises the function of each report section (Table 60.5).

In the second extension activity, after students have reordered a jumbled Discussion section, the instructor asks students to identify an example of the use of evidence from sources in the Discussion. Students are also asked to identify an example of a word or phrase of the language of evaluation. After feedback and discussion about how these features develop the argument, the instructor invites students to highlight other examples of the use of evidence as well as evaluative language (Table 60.6).

In the next extension activity, students are asked to comment on the kinds of language features they used to decide on the order of the Discussion stages so that the ideas and the argument flow (Table 60.7). If necessary, the instructor then introduces language terminology (a language to talk about language) to make these structural and language features explicit (Tables 60.7 and 60.8).

A.2 Runsheet and Lesson Plan

It is assumed that the instructor has a whiteboard and/or a computer with projector for all stages of this exercise.

Instructor and students do…
Extension Activity 1 (30 min) *Instructor:* Provide jumbled up examples of extracts from sections of a whole report (Table 1). Ask students to work in pairs to identify, order, and justify their choices for each section. Facilitate whole-class discussion and summarise students' reasons for choosing the sections of a report in terms of features of factual versus persuasive writing (Table 2). *Students:* Read extracts and identify where in the report the extracts belong and their order. Discuss the reasons for their choices in pairs and as a class. *Resources:* Extracts in Table 1 (or similar); Table 2.
Extension Activity 2 (15 min) *Instructor:* After students have reordered a jumbled Discussion section, provide them with the completed Discussion. Ask them to identify an example of evidence from sources in the Discussion and an example of the language of evaluation. Then ask students to highlight other examples of evidence from sources and evaluative language in the same example. Facilitate discussion and record students' highlights Explain how these features are used to develop the argument (Table 3). *Students:* Identify examples of evidence from sources and evaluative language Contribute to whole class discussion *Results:* Complete Discussion section highlighted (Table 3).
Extension activity 3 (15 min) *Instructor:* Ask students to identify the structural and language features they used to order the extracts in the Discussion. Facilitate discussion and record students' features. Highlight them in the Discussion example (Table 4). If necessary, introduce language terminology to describe these structure and language features (Table 5). Summarise all features used to develop the argument in the Discussion in Table 5 *Students:* Identify structure and language features. Contribute to class discussion. *Resources:* Complete Discussion section highlighted; Table 4 or similar; Table 5.
Total duration in-class = 60 minutes

Notes

Table 60.4 Extracts from sections of a student report on establishing the quality of a potential supply of drinking water (with answers)

Extracts from sections of student water quality report	Report section
Extract 1. Among the 8 replicates in the experiment, the final density of bacteria in the rainwater tank water ranged between 1690 CFUs per ml and 21 4000CFUs per ml, while the density of bacteria in the control water ranged from 0 CFUs per ml to 2000 CFUs per ml.	4. Results
Extract 2. All water supplies for human consumption must be tested and found to reach appropriate standards in terms of quantity and quality of the water (NHMRC 1996). This applies to individual sources, such as domestic rainwater tanks, as well as to large scale sources such as reservoirs, (Mobbs 1998). Drinking water may be contaminated in many ways … The aim of this experiment is to decide whether samples of water, taken from a domestic rainwater tank, are fit for human consumption. The decision is based on the results of a count of the number of colony forming units (CFUs) in the sample of water.	2. Introduction
Extract 3. Two samples of water were tested using a serial dilution technique. The experimental sample used rainwater tank water and the control sample used sterile water.	3. Methods
Extract 4. Establishing the Quality of a Potential Supply of Drinking Water from Rainwater Tanks, using a Serial Dilution Technique	1. Title
Extract 5. Since such a large number of bacteria were detected, it is necessary to limit the microbial contamination by repairing the disinfection/filtration equipment and by flushing or upgrading the distribution system (USEPA 1998. The NHMRC (1996) also suggests identification of the dominant organisms present or the species level of coliform to determine the nature of the contamination.	5. Discussion
Extract 6. Rizak, S., Cunliffe, D., Sinclair, M., Vulcano, R., Howard, J., Hrudey, S., & Callan, P. (2003). Drinking water quality management: a holistic approach. *Water Science and Technology, 47(9),* 31-36.	6. References

Table 60.5 The functions of report sections and typical writing features

Writing features and functions of each section (Factual or Persuasive)	Section of report
Factual: to tell the reader the topic of your report	Title
Factual: to give the reader enough background information so they grasp the context and purpose of your experiment Persuasive: to provide an argument for doing the experiment	Introduction
Factual: to tell the reader what you did, the material you used, the procedure you followed	Methods
Factual: to tell the reader what you found	Results
Persuasive: to interpret, evaluate, explain and argue about the significance of what you found	Discussion
Factual: to tell the reader the origin of the references you cite in the text	References

Table 60.6 Discussion section of water quality report showing logical stages, use of evidence (*italics*) and evaluative language (**bold**) to develop the argument

The statistical analysis of the results show that the density of bacteria in the domestic rainwater tank was not **significantly different** from the **current recommended** standard for **safe** drinking water of 100CFUs per mL or less *(School of Biological Sciences, 2000).* Despite this, the water is not recommended for human consumption because all CFU values **exceeded** the recommended standard *(NHMRC 1996)* and there was a **large** amount of variation among the samples.	Relate to aim Refer previous research Relate to aim
The experiment produced **unexpected** control results which detected the presence of bacterial colonies in **supposedly** sterile water. The controls serve to identify the number of bacteria that arise during the experimental procedure and can indicate **poor** technique. The variability in the range of the eight replicates was also consistent with **poor** technique**.** However, some of the variability is accounted for by the uneven distribution of bacteria through the samples with aggregations occurring particularly in the sludge.	Explain results
Greater accuracy in the counting of CFUs with more replicates and only one group performing the experiment is required in future experiments. In addition, the rainwater samples should be mixed **thoroughly**, with an **improvement** in sterilisation techniques.	Discuss limitations
Since the level of bacteria in the rainwater tank is above the **recommended** standards, an **adequate** treatment technique utilizing coagulation, settling and filtration along with **appropriate** disinfection is **essential** to **improve** the water quality *(NHMRC, 1996).*	Discuss limitations Recommend improve-ments
Although the results indicate that the rainwater is not **fit** for human consumption, further tests are required to determine the extent and sources of contamination so that **appropriate** treatments can be carried out.	Explain significance Conclude

Table 60.7 Discussion section of water quality report showing use of modality and present tense (underlined) to make generalisations and recommendations. Flow of ideas using conjunctions (**bold**), reference words (***bold italics)*** and key vocabulary items (*underlined italics*)

The statistical analysis of the *results* show that the density of *bacteria* in the domestic *rainwater* tank was not significantly different from the current recommended standard for safe drinking *water* of 100CFUs per mL or less (School of Biological Sciences, 2000). **Despite *this***, the *water* is not recommended for human consumption **because** all CFU values exceeded the recommended standard (NHMRC 1996) and there was a large amount of *variation* among the samples.

The *experiment* produced unexpected *control* *results* which detected the presence of *bacterial* colonies in supposedly sterile *water*. The *controls* serve to identify the number of *bacteria* that arise during the *experimental* procedure and can indicate poor technique. The *variability* in the range of the eight replicates was also consistent with poor *technique* and *experimental* error. **However**, some of the *variability* is accounted for by the uneven distribution of *bacteria* through the samples with aggregations occurring particularly in the sludge.

Greater accuracy in the counting of CFUs with more replicates and only one group performing the *experiment* is required in future *experiments*. In addition, the *rainwater* samples should be mixed thoroughly, with an improvement in sterilisation *techniques*.

S**ince** the level of *bacteria* in the *rainwater* tank is above the recommended standards, an adequate *treatment* *technique* utilizing coagulation, settling and filtration along with appropriate disinfection is essential to improve the *water* quality (NHMRC, 1996).

Although the *results* indicate that the *rainwater* is not fit for human consumption, further tests are required to determine the extent and sources of contamination **so that** appropriate *treatments* can be carried out.

Table 60.8 Summary of resources useful for developing an argument in a laboratory report Discussion section with examples

Resources	Function
Using logical structure	Present information using the stages of the discussion (Table 3 and Figure 2)
Using evidence Sources	Refer to sources, outside authorities *(all CFU values exceeded the recommended standard* ***(NHMRC, 1996)*** Refer to sources with more or less support or certainty *(The NHMRC (1996) also* ***suggests*** *… Mobbs (1998)* ***claims*** *that a one-off leakage is …)*
Comparison	Introduce similar ideas/ results to support your evaluation *(The variability in the range … was also* ***consistent*** *with* ***…)***
Contrast	Introduce contrasting ideas/ results to support your evaluation *(****However****, some of the variability …)*
Concession	Acknowledge opposing positions in less powerful ways *(****Although*** *the results indicate …, further tests are required****)***
Using language Vocabulary	Vocabulary for positive *(****adequate*** *treatment)* or negative meanings *(****poor*** *technique)* or intensifying meanings *(****considerably*** *higher)*
Using language to modulate meanings (modality) and verb tense	Express degrees of certainty *(Drinking water* ***may*** *be contaminated* ***…****),* frequency *(****all*** *CFU values)* or obligation *(it is* ***necessary*** *to limit …).* Past tense for stating facts (your results), present tense and modality for making generalisations/ evaluations /interpretations.
Creating flow (cohesion)	Use conjunctions, reference and vocabulary to link ideas together in a logical way (Table 4)

Top Tips for New Instructors

1. Some language features may need more explanation, for example, the modal verbs (may, might), nouns (possibility), adjectives (possible) and adverbs (possibly). Also it may be useful to address the appropriate use of conjunctions (e.g., because, although, in addition, furthermore) and that they are not

necessary in every sentence; the meaning can be made with other language (e.g., is accounted for).

Further Reading

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Organising Your Communication Using Mind Maps

61

Mariela Soto-Berelov, William Sullivan, Belinda Bold, and Samantha Le-May

Organising - Investigating - Arguing

61.1 Learning Outcomes

This activity helps students get started when facing a large task (such as a presentation or written report) by developing a mind map (RMIT University 2021b). Through mind mapping, students develop skills for organising, distilling information, and designing a presentation; written, visual or oral (RMIT University 2021c).

After this lesson, students will be able to visually organise their assignments, from analysing the task and planning, through to writing and editing the assignment (RMIT University 2021d). This activity encourages students to put their thinking on paper and, through a process of planning, researching, writing and editing, be able to present their clear and coherent ideas to a broader audience.

Learning the mind mapping process is also a useful tool for teams; the map helps team members organise themselves to plan and map the elements of work that each member will do. The map also helps the team members set time frames, exchange feedback, and check the drafts of each element and tie them together as they progress.

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61.2 Teaching Context

Students can use mind maps for planning any individual or team-based assignment, tracking their own work and editing. We use this activity to help first-year undergraduate students get started when doing a team-based presentation on a contentious topic in the sciences. After students choose a topic, they brainstorm together to create a mind map that contains the main ideas relevant to their topic. Students are encouraged to use this as an opportunity to delegate responsibility across team members and support each other.

This activity is used both in person and online. It could be completed in 1 h but expanded to last 2 h (or more) if combined with other activities (last steps in Lesson Plan). Students can also revisit their mind map to track their progress as they continue working on the assignment. Instructors can opt to monitor the mind map development to ensure students are progressing in their work.

61.3 Overview of the Teaching Activity

The activity introduces the concept of a mind map through an example and a discussion about the use of mind maps for individual and team-based assignments. The instructor points out the utility of mind maps for clarifying the key concepts of a topic, showing links and relationships between ideas, indicating research required, and storing reference details. Mind maps help scaffold the learning and encourage team feedback, ultimately saving time.

Students begin by analysing the assignment topic in their own words and noting what they already know about it. Students then organise their ideas through a hierarchical structure, raising questions about the knowledge needed and indicating research required.

In a face-to-face learning environment, the instructor provides paper and coloured pens. For online mind mapping, instructors are encouraged to investigate available software (see recommendations below).

Depending on available time, students can finish the activity and then present it to the class or continue working outside of class. Students can be encouraged to keep building on their mind map, and use it to edit, then practise the delivery of their presentation (mind maps assist research and memory through key words).

61.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
"Where do you live?" Icebreaker Set up posters around the room representing north, west, south and east. Facilitate discussion about where people live relative to the current location (1).	Students stand roughly where they live, take turn introducing themselves, their study interests and the program they are doing and say something they like about where they live.	Pens or markers. Post-it notes or butcher's paper. 10 min
Introduce the activity. Explain objectives and outcomes. Ask students if they are familiar with the concept of a mind map (if online, can do a poll) (2).	Students contribute their ideas about mind maps (i.e., Do they know what it is? Have they done one before?).	5 min
Discuss assignment requirements. Explain the concept and relevance of mind maps to the planning and research stages of the assignment (3). Refer to students who have used mind maps. Ask about their experiences.	Students share their prior experience. Students should have prior access to assignment brief and rubric.	Example mind map. See link: *What are mind maps*. 10 min
If necessary, facilitate team formation. Invite students to begin mind map for their assignment (4). Circulate to encourage students. Facilitate and guide student discussion (e.g., "Some great ideas here, could you explain this one to me?" (5).	Students work on their mind map individually or in teams. See (6-9) which includes getting started (6), linking ideas (7), researching (8), editing (9). See references for RMIT University (2021)	Material to write and draw or computer software. See link: *How to create a mind map* and *Group work 101*. 30+ min

Summarise objective of activity and encourage students to use the mind map as a living document throughout their assessment. Facilitate discussion through guided questions.	Students reflect and discuss their map. Questions: What did you learn? What were the challenges? How do you see it changing throughout the assessment?	 5 min
Extension If the assignment objective is to do a presentation, the mind map can be used to practise speaking in front of an audience. Ask students (individuals or teams) to present their mind map (10).	*Extension* Students present their mind map individually or in teams. Audience may offer feedback.	Created mind map. Time to prepare. Place to present. 30+ min
Extension Students use the mind map to create headings for their assignment (11).	*Extension* Students create headings for their assignment.	Assignment brief and rubric. See links: *Report writing* 30+ min
Total duration in-class = Minimum 60 min but can be extended (~2 hours) through extension activities.		

Notes

(1) Icebreakers can help create a safe learning environment, which encourages student engagement. The provided example is for face-to-face delivery. If working online, a "what we have in common" icebreaker works well. In this activity, students work in groups to identify five things they have in common.

(2) Engage students in content to help the instructor and students identify their current knowledge and skills as well as those required.

(3) Explain some of the uses and purposes of mind maps through an example. There are many examples (see website resources). We do this item in conjunction with an assessment item to give students a focus for their mind mapping. If available, students can also be given (or referred to) assignment documents such as instructions, rubric, checklist.

(4) Students can use mind maps to organise and develop key words to research individual or group tasks. The instructions given here are around helping students get started on researching their assignment topic. Students can also make mind maps of other processes associated with an assignment item, such as collecting data, structuring writing, etc.

(5) Interacting with students allows the instructors to identify and address specific learning needs. When facilitating discussion, consider the questions posed to students, which should be open in nature yet answerable. Questions should guide students to generate the appropriate answers, building their confidence and independent learning. Be sure to embed encouragement in questions and use students' names.
(6) Students start by putting the assignment topic in the centre circle. They then write down every idea they have about their assignment topic, including key concepts and key words. Students then review the ideas they wrote down to ensure they are clearly linked to the topic.
(7) Students progress to the next stage—linking the key ideas to each other on the mind map (in a hierarchical manner), crossing out the notes that are not relevant, and adding new notes of any more relevant ideas (see mind mapping resource).
(8) Students use the key concepts and key words recorded on their mind map to begin searching for references relevant to their topic (research). They add notes and some reference details to the mind map to keep track of the research conducted. As the notes expand, the mind map can give way to a more lineal plan on a shared document, always retaining the referencing details with the notes.
(9) When editing a draft of the assignment, refer back to the mind map as a simple and quick way to check that all key concepts have been covered, all the links between concepts have been made in the text or presentation slides and that all concepts link back to the assignment topic (in the centre of the mind map).
(10) Once students have created their mind maps, they then present these to the group or class, thereby practising their public speaking and presentation skills.
(11) Students can refer to the mind map to create headings for their assignment. If working on a presentation, they can decide what relevant information should go in each slide; if working on a written report, they can create appropriate section headings. They can also use this as a checklist to ensure assignment requirements are being met.

61.5 Top Tips for New Instructors

- Before teaching this activity, new instructors should review the website links and references which fully explain the mind map concept and provide examples.
- Warm up with an icebreaker that leads to an explanation of a mind map.
- Allow for pen on paper or online mind map development, dependent on the teaching environment and student preferences.
- Adapt each activity to suit the purpose and cohort, encourage creativity, such as text, diagrams and colour.

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Facilitated Road Maps: Coaching Students to Embed Planning in Major Communication Projects

62

Bethann Garramon Merkle

Organising - Intent - Working

62.1 Learning Outcomes

Training university students as effective communicators requires authentic, beyond-the-classroom projects and audiences. Often, such projects are multi-faceted and do not have straightforward, "right-answer" outcomes. Helping students organize such projects into feasible components remains a challenge, as many students struggle with time management (Misra & McKean, 2000; Collier & Morgan, 2008), juggle competing obligations (e.g., Guastella, 2009), and are rarely experienced in project planning before they arrive in our classes. A facilitated approach makes it more feasible for students to develop planning skills, and templates make it easier for instructors to embed project planning into a scaffolded sequence of assignments.

By the end of this planning process, students will be able to (1) accomplish essential project planning and management tasks and (2) leverage planning templates for communications projects outside the classroom.

62.2 Teaching Context

I have coached students through the planning of major communication projects at undergraduate and graduate levels. Students struggle with time management, often because they are not confident in how to break down a major, longer term project into feasible increments. Students are also challenged by estimating the amount of time tasks will take.

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Rather than doing all of the work of breaking down project phases into assignments for students, this chapter will enable students to guide their own work. By providing learner choice, instructors facilitate active learning and build students' abilities to transfer skills from our classrooms to the real world. Thus, when instructors embed planning itself into the scaffolding of major projects, students can develop feasible project road maps which inform their work in and beyond the course.

62.3 Overview of the Teaching Activity

In the first part of this exercise, students reflect on a prior, complex project. They consider how they felt about trying to manage and complete the project. They then compare that experience to what they anticipate the assigned project will be like. Students work in groups and as a full class to discuss what they look forward to, what will be challenging, and what they are confident about. Finally, students work through a sequence of prompts designed to help them identify all the subsidiary tasks of the assigned project, which are priorities, how long they will take, and how to schedule both due dates and work time for each task.

Students can work through a planning process in a single class period or over several class periods if the project is more complex. Ideally, the instruction sequence would include assignments in which the students reflect on their plans regularly (at least at the quarter, mid-point, and three-quarter stages, as well as a final, post-project reflection). By requiring reflection on the efficacy and accuracy of their planning, we also encourage students to practice meta-cognitive skills (thinking big picture about their experiences, process, etc., versus just doing the task). Such skills are essential for building self-efficacy and recognizing transferable skills.

62.4 Runsheet and Lesson Plan

This chapter outlines a 1-h facilitation sequence (which can be extended to 2 h) for the initial planning process (Note 1, 2). Instructors can facilitate students through the whole activity as they begin the planning stage of a project or spread the process over more than one class period. Some aspects of the sequence can also be assigned as homework.

Discussion in class is essential. Students need to hear about their peers' planning strategies, and most students will not adequately breakdown a complex project if left alone to draft a task list. Further, instructors can efficiently assess whether students have a realistic task list and time estimates by facilitating the planning process during class. I encourage instructors to provide samples of the activity stages for student reference by creating examples or using past students' work.

Instructor and students do….
INTRODUCTION *Instructor:* Before class, introduce students to the major project, whatever that may be in your class. During class, provide time for students to discuss the major project, ask instructor questions, etc. (1, 2).
REFLECTING ON PAST EXPERIENCE (10-20 min) *Instructor:* Establishes foundational expectation that past experience informs current work (a key transferrable skill students practice/gain from this activity). *Students:* Reflect on a past project, using a think/pair/share activity sequence (3).
CONNECTING THE CURRENT PROJECT TO PAST EXPERIENCE (10-15 min) *Instructor:* Reinforce expectation that past experience informs current work. *Students:* Use instructor-facilitated reflection (think/pair/share) and the project description to make connections between past work and current project.
ANTICIPATION & EXPECTATIONS (5-15 min) *Instructor:* Emphasize a growth mindset: the project is possible, it just takes planning and work. (5). Facilitate group brainstorming (pair/share or full class) around the project. *Students:* Articulate expectations and what they anticipate from this project.
SEGMENTING PROJECT INTO DISCRETE TASKS (4) (10-30 min) *Instructor:* Facilitate group brainstorming (pair/share or full class) to segment the project into discrete tasks. *Students:* Work in pairs/groups and as a full class to identify all the specific tasks they will need to complete (6).
PRIORITIZING TASKS (10 min) *Instructor:* Help students understand that this process will mean less stress and less rushed work later. *Students:* Working in pairs, categorize tasks in order of priority, then in order of when the tasks should be completed.
ESTIMATING TIME COMMITMENTS (10-30 min) *Instructor:* Help students understand this is the most challenging aspect of planning and completing a complex project. Give the students plenty of time here, and help them make realistic estimates (they will likely under-estimate). *Students:* Identify tasks similar to those completed in prior work and make time estimates. Complete time estimates for all remaining tasks.

BALANCING THE PROJECT WITH OTHER TIME CONSTRAINTS (5 min) *Instructor:* Acknowledge students have commitments outside of our class (7). *Students:* Mark down existing, known commitments in calendar. Resources: See Appendix 1.
GROUPING TASKS, AND NOTING DUE DATES (5 min) *Students:* Identify tasks that should be completed in a batch and mark associated personal deadlines and assigned due dates in calendar (7). *Time:* 5 min
SETTING PERSONAL DEADLINES AND SCHEDULING WORK TIME *Students:* Identify and mark in calendar their personal deadlines for tasks. Mark in calendar work time necessary to meet personal deadlines and assigned due dates throughout project.
Extension SELF-CHECK ON TIME MANAGEMENT AND PROJECT STATUS (20 min) *Students:* Use a think/pair/share (3) sequence to reflect on how work/time management compares to plan at ¼, ½, and ¾ points in project, e.g., weeks 1, 2, and 3, of a 4-week project (8).
Total duration in-class = Minimum 60 minutes, but can be up to 2+ hours. Time depends on complexity of project and how much coaching students need to identify tasks and make time estimates and schedules.

Notes

(1) This lesson plan assumes that students have already been introduced to the major project and have had an opportunity to discuss it, ask questions of the instructor, etc.

(2) Appendix has a detailed facilitator script to guide student reflections and work through all stages of this lesson plan. Detailed script provides time alternatives for 1-h and 2-h version of lesson plan.

(3) In "think/pair/share" activities, students are first asked to think about the prompt/task by themselves for a few minutes. Then they discuss with a partner (pair) or a small group (<5), before each group shares out to the full class. This sequence gives students time to process what they want to say or questions they want to ask before being "put on the spot" in front of the whole class. Peer support or pressure, in the form of partners and small groups, in this sequence can also help students learn collaboratively and not withdraw if they are uncomfortable or disinterested in the activity.

(4) Task segmentation is one of the most challenging aspects of major projects, so do not skimp here.

(5) Encouraging students to use a growth mindset is not as simple as telling them to. Many students may not be familiar with the concept, so clarifying the distinction between growth and fixed mindset may be necessary (Dweck, 2006). One way to introduce the growth mindset idea is to share with students (perhaps as homework before the planning session) a story such as *The Dot* (Reynolds, 2003). The book follows a young girl frustrated at her art skills and the teacher who inspires her to trust herself. While it is a so-called children's book, I have successfully used this story in numerous university courses and trainings for scientists and science educators. The book is also available as a recording on YouTube, making it easy to embed in most content management systems as an assignment link. A link is not provided because access/availability may depend on your location globally.

(6) Instructors will want to make a list in advance, to "seed" the discussion or keep it going if students run out of ideas.

(7) Over several decades in the USA, nontraditional students have comprised at least 70% of the country's undergraduate population (Radford et al., 2015). Responsibilities which modern students juggle include other coursework, jobs, caregiving responsibilities, military service, volunteer work, etc. By assuming students can devote all their time to our class, or their coursework overall, we perpetuate problematic, exclusionary attitudes in academia (Guastella, 2009; Witkowsky et al., 2016; Schmidt & Hansson, 2018; Shankland et al., 2019).

(8) It is assumed that the instructor has provided intermediate benchmarks/due dates for stages of the major project. Such scaffolding is essential in helping students manage complex assignments.

62.5 Top Tips for New Instructors

1. Providing students with additional, optional resources can reinforce the message that planning is a valuable part of project management within and beyond the classroom. I use and introduce all my students to the Passion Planner, a goals-oriented planner developed by a minority student. The company offers free downloads of all aspects of the planner, making it accessible as a teaching resource.
2. Many students will resist the planning activities, particularly in the early stages. The initial reflections can help open their minds. You will get their attention when they start charting out how many discrete tasks and how much time are required to complete the project. But, they still may not appreciate the utility of the project unless you coach them to regularly reference and self-assess progress against their plans.
3. Examples are essential for (a) underscoring the value of comprehensive planning for the students and (b) demonstrating that you also use planning to accomplish your own professional work. Showing students examples of your own planning process alongside productive examples of student plans can help students visualize how to create and use the step-by-step planning process outlined in this chapter.

Appendix: Detailed Lesson Plan and Script for Facilitated Road Maps

A.1 Detailed Lesson Plan and Script

This script outlines a 1-h facilitation sequence (which can be expanded to 2 h) for the initial planning process (1).

Facilitation notes and script
INTRODUCTION (Prior to this class) Introduce students to the major project, whatever that may be in your class. Provide time for students to discuss major project, ask instructor questions, etc.
REFLECTING ON PAST EXPERIENCE – REFLECTION 1 ***Activity*** **(10 mins minimum - ideally 20 min):** Facilitate Reflection 1 as a "think/pair/share" activity (Think for 3 (5) min; Pair for 3 (5) min; Share for 4 (10) min) ***Script:*** *Think of a major project (school, work, volunteer) you worked on that involved many parts.* *How did you feel when it was assigned/you took it on?* *Was it clear how you should start and work through the project?* *How did you deal with all the complex parts of the project?* *Did you feel like you had enough time to complete it while balancing all your other responsibilities?* *What do you wish you had done differently when doing that project?*
CONNECTING CURRENT PROJECT TO PAST EXPERIENCE – REFLECTION 2 ***Activity (*****10 mins minimum - ideally 15 min)*****:*** Facilitate Reflection 2 (think/pair/share) to reinforce the expectation that students' past experience informs their current work (Think for 3 (5) min; Pair for 3 (5) min; Share for 4 (5) min)
Script: *How does this major communication project compare to the past project you were just thinking about? What seems similar? What seems different?* *How do you feel about accomplishing the goals of the project by the due date?* ANTICIPATION & EXPECTATIONS ***Activity*** **(6 mins minimum - ideally 10-15 min):** Group brainstorming (pair/share or full class) in which students set their own expectations. Instructor should emphasize the growth mindset (Dweck, 2006; Notes 1,2).

Script: *What do you think will be fun or easy about this project? Why? What do you think will be hard? Why?* *Make a list of these "easy" and "challenging" things, then choose the top three in each category. What makes them rise to the top?* *What elements of the project do you feel confident about? What elements might you need help with?* *Who else might need to be involved in this project, for you to complete it successfully?*
SEGMENTING PROJECT INTO DISCRETE TASKS ***Activity*** **(10 mins minimum - ideally 15-30 min):** Students work together to identify all the work necessary to complete their major project. Use group brainstorming (pair/share or full class). ***Script:*** *How many individual tasks can you think of that will need to be completed to accomplish the project goals by the due date? These can be tasks that are exclusive to the project or might relate to/impact it or your ability to focus on it.*
PRIORITIZING TASKS ***Activity*** **(10 min):** Help students organize the tasks in necessary order to complete the key project components on time ***Script:*** *Working with a partner, categorize the list in order of priority. You could use categories like a) absolutely must do; b) optional but ideal; c) optional, could skip if time runs out; d) someone else might do this, but I probably won't for my project; etc.* *Once you have them categorized, organize these items in order of what needs to be done first, next, etc.*
ESTIMATING TIME COMMITMENTS ***Activity*** **(10 mins minimum - ideally 20-30 min):** Help students understand that estimating time commitments is one of the most challenging aspects of planning and completing a complex project. Give the students plenty of time here and help them make realistic estimates (they will likely under-estimate). ***Script:*** *Individually, mark all of the tasks that are similar to tasks you've worked on before. How long did it take you to complete those tasks before? With that in mind, put a time estimate next to each task.* *Be as realistic as you can and consider over-estimating a little to give yourself breathing room. Add up how much time that is; don't freak out! This is to give you a sense of the real time allocation you'll need to plan for. It is doable – students do this project successfully every semester.*

BALANCING PROJECT WITH OTHER TIME CONSTRAINTS ***Activity*** **(5 min):** Acknowledge that students have commitments outside of your class. ***Script:*** *It is important to be realistic about how much time we can allocate to any given commitment as we determine how to be successful at it. So, by yourself, make a list of the other major time commitments you have. Mark those down on your calendar.*
GROUPING TASKS, AND NOTING DUE DATES ***Activity*** **(5 min):** Help students group tasks and assign due dates to them. ***Script:*** *With your other commitments in mind, look again at your list of tasks for this project. What parts of the project look like they could be lumped together, by type of work or by stage of the process? What are the assigned due dates that correspond with these groups of tasks? Mark those in your calendar.*
SETTING PERSONAL DEADLINES AND SCHEDULING WORK TIME ***Activity*** **(10 min):** Help students set their own deadlines. ***Script:*** *Working backwards, using the task-lumping you did, mark down your self-identified deadlines for the tasks that must be completed to meet the class due dates. Finally, use the time estimates you developed to schedule when you will actually work on the tasks to meet your own deadlines and the assignment due dates.*
SELF-CHECK ON TIME MANAGEMENT AND PROJECT STATUS ***Extension*** **Activity (20 min):** Students reflect on how work/time management compares to plan at ¼, ½, and ¾ points in project (e.g., weeks 1, 2, and 3, of a 4-week project). ***Script:*** *Use think/pair/share to reflect on these areas:* *Are you meeting your internal deadlines? Are you meeting assigned due dates?* *What has made this feasible or challenging?* *What can you change about your plan and your approach to it, to meet your goals for the remainder of the project?*

Notes

(1) Encouraging students to use a growth mindset is not as simple as telling them to. Many students may not be familiar with the concept, so clarifying the distinction between growth and fixed mindset may be necessary.

(2) One way to introduce the growth mindset idea is to share with students (perhaps as homework before the planning session) a story such as *The Dot* (Reynolds, 2003). The book follows a young girl frustrated at her art skills and the teacher

who inspires her to trust herself. While it is a so-called children's book, I have successfully used this story in numerous university courses and trainings for scientists and science educators.

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Website Link

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Bethann Garramon Merkle is an Associate Professor of Practice at the University of Wyoming, USA. An award-winning teacher and communicator, Bethann works at the intersections of art-science integration, equity in STEM, and scicomm theory and practice. To date, Bethann has trained over 2000 scientists and science students in inclusive scicomm and has impacted the field through major initiatives at UW and in the Ecological Society of America.

Part XIII

Practice Working

Building Your Personal Pitch Using a Message Framework

63

Kristy L. Daniel and Cynthia J. Luxford

Working - Speaking - Distilling

63.1 Learning Outcomes

Have you ever tried to talk to someone about your research, but felt as if you were talking to a wall? While some people find science interesting, others find it boring or difficult to understand. If scientists cannot successfully share their research with others, the value of their work will be lost.

Being able to Initiate a conversation about science and communicate the critical purpose of scientific research to others is essential. Science graduates will use these skills when providing outreach that supports development of scientific literacy, applying for funding, explaining science to policy makers, networking at meetings and, of course, in job interviews where they talk about themselves and their science.

Through completing this exercise, students will learn techniques to structure and create a personal messaging pitch to verbally communicate their credentials and scientific research to improve their networking skills.

63.2 Teaching Context

Anyone can become effective at sharing science messages if they take time to understand their audience. We do not need to water down science, but rather scientists need to use a common language their audience understands to share their message.

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This communication framework lesson has helped over 150 graduate and undergraduate students create personal pitches to introduce themselves and their science stories. This activity works best with students that are actively engaged in scientific research activities.

63.3 Overview of the Teaching Activity

This lesson can be integrated into classroom activities or run as an independent workshop. Start by presenting students with background content about communication needs, public responses to science, communication theory (optional), the role of jargon on cognitive load, and general communication principles. The other chapters in this book will be very helpful for this! Also remind students that they will be using a concrete framework (or "formula") for their communication design (so they do not need to just make it up!).

Each student crafts a ~30-s, introductory elevator pitch following a basic structure and check their work for jargon flags. Students practice introducing themselves to others while giving their pitch, allowing them to become comfortable with networking and speaking. In an optional extension activity, students expand their pitch using a scaffolded approach to create a longer presentation of their scientific research. The longer presentation template uses a lead, set-up, three talking points, and take-home point structure.

63.4 Runsheet and Lesson Plan

Instructor does...	Students do...	Resources
Provide Communication Planning Worksheet (1).	Complete a Communication Planning Worksheet.	Worksheet
		30 min
Introduce students to the importance of understanding audiences and the role of communication in science (2).	Consider their audience. Students may wish to define a target audience for their pitch at this time.	See relevant chapters in this book.
		20 min

Instructor does…	**Students do…**	**Resources**
Describe the importance of bridging the cognitive gap (what is presented by the speaker that is not understood by the listener) caused by jargon and context. Show the TedTalk “Talk Nerdy to Me” Demonstrate how to identify jargon using De-Jargonizer (3).	Practice using De-Jargonizer by copying and pasting provided examples. Work in groups to remove jargon while maintaining context and message quality.	Provided text examples Talk Nerdy to Me De-Jargonizer 20 min
Review the goals (4) and parameters (5) for an elevator pitch. Allow time for jargon review and revision.	Begin crafting elevator pitches. Use the communication planning worksheets, pare material down, and focus on three essential elements (6).	Completed Planning Worksheet. 30 min
Pair students up. Offer encouragement and suggestions to students on how to improve their pitches as they practice.	In pairs, practice giving pitches. Switch partners every few minutes, so students “meet” more people (7).	Developed Pitches 20 min
Total duration in-class = Minimum 70 min but can be up to 2+ hours, depending on size of class and time allowed for developing and practicing presentations.		

Notes

(1) Can be completed before or during class.

Communication Planning Worksheet Questions

(a) Describe your research topic in no more than three–five sentences.
(b) Why are you personally interested in studying your research topic?
(c) What do you hope to do/accomplish through your research?
(d) Assume that you are about to have a conversation about your research with a person who does not have any background in your field. At most they might have studied introductory science at high school. What do you think this person may already think they understand/believe about your research topic (even if it is not scientifically accurate)?
(e) Now think about why this same person might have any interest in your research topic? (e.g., is there an economic, ecological, health-related, entertaining, controversial, political, or other reason?)

(f) What is the ONE most important outcome of your research? (Think about why someone else, like a person with no background understanding in your field, should care about your study results.)
(g) Imagine that I am the person with no background understanding in your field. Describe your research topic to me in no more than three–five sentences. You are not allowed to use terms/phrases I do not understand.
(h) What are three questions this person might ask you about your project?
(i) Using evidence from your research, how might you answer the three questions asked of you above?
(j) What is ONE interesting or unusual fact, amazing statistic, challenging question, or personal story related to your research?

(2) For example, show students a visual illusion of a rabbit/duck (https://en.wikipedia.org/wiki/Rabbit–duck_illusion) and ask students what they see. This example can show how prior ideas and individual perspectives can influence how people interpret messages. Note that it is also safe to assume that everyone you meet will have no clue what your research is about, as less than 0.1% of the global population are scientists.
(3) See Chap. 10 for a chapter by the authors of De-Jargonizer. People need to understand at least 98% of the words used to understand communications. Thus, the aim for general messages involving the general public should include no more than 15% mid-frequency jargon, no more than 5% rare jargon, and a suitability score of 90 or higher.
(4) An elevator pitch is a short, concise, pre-planned presentation that tells your story. The term "Elevator Pitch" suggests that you should be able to deliver your message in the brief time of an elevator ride (about 20–40 s) with the idea that you present this message anywhere at any time—conferences, interviews, family events, parties—even if you happen to meet someone by chance in an elevator.
(5) *Be Concise*: Make it short, sweet, and to the point.
Be Clear: No Jargon!
Show your Passion: If you are not passionate about your topic, how can you expect anyone else to be?
Create Visual Imagery: Use words that paint a picture.
Frame a Story: Do not forget to tell your story and the story of the research.
Consider what is the worst that could happen? What will people miss out on by valuing your research.
(6) Three essential elements of an elevator pitch: (1) Offer a greeting and state your name and who you are (e.g., graduate student, fellow, undergraduate researcher); (2) Describe your thesis research topic in no more than three–five sentences without jargon. Make sure to include why you are personally interested in studying your thesis research topic and why others should care about what you do; (3) Include a statement on what you hope to do and/or accomplish. The authors' bios at the end of this chapter are two examples of elevator pitches that follow these elements.
(7) You can assign practice pitches as homework, but remember not all students have a network of people they can practice on, so it is worthwhile helping

students connect outside of class (e.g., invite them to use the course Discussion Board or similar). You may also want to run another celebratory session in which students return with their final pitches and give them to the whole audience.

63.5 Top Tips for New Instructors

1. Scientists are essential players in science communication, but science can sometimes seem accessible only by the elite. This disconnect can lead to a lack of public trust, understanding, engagement, and even funding. Unfortunately, not all scientists know how to communicate what they do to in ways that connect with non-science audiences. Communication is a two-way process and success is only attained when both parties have the same understanding about what is being communicated.
2. We found that students often struggle with understanding (a) the big picture ideas associated with their research goals and (b) the challenges presented by using jargon. Communication barriers, such as jargon, can distort or destroy messages. Often, jargon use can also hide a student's limited understandings about their own research or science content. When we strip away technical language, students must find their own words to explain their work. This requires deep research understanding from the communicator. Visualizations can help overcome language barriers, but visual images are not always available, especially during unplanned networking conversations. To replace visualizations, encourage students to try using purposeful gestures, verbal imagery, and analogies.
3. Most students struggle with decisions about how to introduce and share their research with others. Our formulaic scaffold helps provide initial direction and improve confidence.
4. The primary goal of an elevator pitch is to keep your focused message brief. These pitches should be under 40 s in length and have a single clear focus or frame that places the research message into a relatable context. By the end of the pitch, people should have a reason to (a) care about the speaker's message and (b) start a conversation about the pitched idea.
5. When creating elevator pitches, use humor sparingly and carefully. Sharing a joke can create a bond, but we are not stand-up comedians and failed attempts can be embarrassing (or even offensive). Jokes should be pre-planned, and humor should be used only if it can help punctuate a thought to help an audience remember the point being made.
6. It is okay if the first attempts at an elevator pitch are not great—the iterative drafting process is important! Reassure students they do not need to rush their pitch development as it will become one of their most important and well-used networking messages.

Further Reading/Exercises

Students may be interested in expanding their pitch to develop a Three Minute Thesis to showcase their research. Many universities host their own competitions.

Website Links

Communication Planning Worksheet. (https://www.dropbox.com/s/upoim0v2z4ihy19/Communication%20Planning%20Worksheet.docx?dl=0). *Accessed 20 Jan 2021*
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Talk Nerdy to Me. (https://www.ted.com/talks/melissa_marshall_talk_nerdy_to_me?language=en). *Accessed 15 Jan 2021*

Dr. Kristy L. Daniel, an Associate Professor of Biology at Texas State University, studies how people communicate science. When scientists share their research, what they mean to say is not always what is understood. This is especially true when using images. She explores what causes gaps in communication and identifies ways to improve message bridges. Her goal is to help make science accessible to more people by creating better messengers.

Dr. Cynthia J. Luxford, an Assistant Professor of Chemistry at Texas State University, studies ways to help students succeed in introductory science classes. She explores how students' past experiences can be used to help them learn new material. Her goal is to encourage students from diverse backgrounds to pursue science careers and to make science obtainable to everyone.

How to Be a Functional Team Member

64

Amanda Rasmussen and Louise Kuchel

Working - Conversation - Organising

64.1 Learning Outcomes

Group work is a main-stay of workplace practice and is increasingly common in higher education assessment. This series of short activities supports students as they develop a professional and accountable approach to academic group work, while providing opportunity for students to address common group work grievances. Students learn some basics for how to:

- set appropriate team expectations based on individual strengths,
- appreciate diversity,
- reflect on the progress of themselves and the team, and
- negotiate contributions to the team product.

Supplementary Information The online version contains supplementary material available at [https://doi.org/10.1007/978-3-030-91628-2_64].

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64.2 Teaching Context

These activities work well when accompanying longer-term group projects or assessments (for examples, see Kuchel et al., 2014; Rasmussen et al., 2011; Wang & Rasmussen, 2021). We have used the activities at all levels of science undergraduate coursework in both the UK and Australia. They are also suitable for postgraduate level and all science (and other) disciplines. The activities address employability and transferable skills.

The sequence consists of four activities, each about 30-min duration, and a peer evaluation. They work well when implemented at different stages that align with the progress of a group project. The four activities are derived from evidence-based literature.

64.3 Overview of the Teaching Activity

There are four sessions.

Session 1 (Team forming) focusses on expectations of team members, personality types, and role allocation/discussion. It includes an icebreaker and several targeted discussion activities.

Session 2 (Reconciling differences) highlights negotiation skills and techniques through role plays.

Session 3 (Reflection) requires students to reflect on their behaviour to date and that of their team as a unit (in accordance with the pre-discussed expectations set in the first session).

Session 4 (Author order) requires students to negotiate author order based on each members' contribution styled around negotiating authorship order for journal submissions.

The four sessions are followed by an anonymous peer assessment.

The student and teacher guidelines are available in Appendices 1–9 for this chapter.

64.4 Runsheet and Lesson Plan

The following runsheet describes how we used these exercises in a large class for first-year undergraduate students. We have also expanded and separated tasks from each session to embed them within longer tutorials covering a large group assignment and with more advanced students. Notes on how to expand the activities are after the table.

Instructor does…	**Students do…**
Session 1: Team forming (30 min)	
Introduce what it means to work in a team (1) and facilitate student discussions	Discuss their expectations of team behaviour (2).
Explain personality types and facilitate discussion	Discuss their personality types within their groups (3).
Explain negotiation task (6) and facilitate student allocation of tasks.	Make a list of tasks for each member (4) (5).
Resources: Student notes (Appendix 1) and Teacher notes (Appendix 2).	
Session 2: Reconciling differences (30 min)	
Provide negotiation task information (7) (8).	Negotiate and decide who gets the land.
Explain good negotiation practice.	After learning about negotiation, try task again.
Facilitate discussion about negotiation; link this to students' contributions to their group project. Before end: explain reflection task	Discuss what they learnt and how it could apply to their groups (9)
Resources: Student notes (Appendix 4 and 3), Teacher notes (Appendix 5)	
Session 3: Reflection (30 min)	
Invite students to reflect on their behaviours during the group's work	Complete self and group reflection sheet
Facilitate student group discussions about their responses (10)	Consider group discussion about progress
Resources: Student notes (Appendix 6) and Teacher notes (Appendix 7)	
Session 4: Workload/Author order (30 min)	
Remind students of what they have learnt in each session then facilitate author order task (11).	Negotiate author order based on contributions to the task (12)
Resources: Student notes (Appendix 8) and Teacher notes (Appendix 9)	
Anonymous peer assessment	
Students Mark each other anonymously (13)	
Total duration in-class = 4 x 30 min activities each of which can be lengthened or shortened depending on needs and context	

Notes

(1) Points to raise: what is a team, different personalities and working preferences (Information to facilitate this discussion is provided in Appendix 1).

(2) If students get into a discussion about what they expect, then a bit longer than 5 min can be beneficial. Do not spend the time talking at the students—let them take the lead.

(3) We do this informally in our classes, but it can be useful to use diagnostic tools such as Myers–Briggs or others before or during class.

(4) It may be beneficial to get students to sign off on their behaviour expectations and task allocations at this point.

(5) We used these activities to accompany a video assignment. Tasks for the video include reading papers, filming, interviewing, and more. Not all students will necessarily contribute to all tasks required to complete the assignment. Ensure that all students in a group have agreed on a method to contact each other out of class.

(6) The negotiation task is confronting. It is important that students become comfortable with the idea of negotiation. They also need to link the negotiation activity to the idea they will be negotiating about their contribution to the group, and hence will be held accountable for their contribution.

(7) The point of this exercise is that there are two sides of a negotiation. In the provided examples, the parties need different parts of the same block of land to reach a mutual agreement. When implementing the negotiation activity, one person receives one side of the argument and the other person in the pair receives the other side of the argument. No student should be provided with both sides of the argument at the beginning.

(8) At the start of this activity we give students the information in Appendix 4 (student notes for session 2). When students are part way through their negotiation, or if time is available to extend the negotiation, we give students the supplementary handout in Appendix 3. Teacher notes are in Appendix 5.

(9) It can help to get students to write a paragraph on what they have learnt.

(10) Ensure students focus on the job at hand rather than making the discussion personal. A useful approach is to get each student to reflect and tell the group one thing they are doing well, then one example of how they can improve their behaviour, and then another thing they are doing well. Then, ask students to do the same for the group as a whole. You can also help students to begin a discussion about their contributions (in preparation for the final training session).

(11) This is the most confronting of the tasks. Groups that have experienced conflict may benefit from the instructor mediating part of the discussion.

(12) This is a representation of academic negotiation. Co-authors are usually required to provide an author contribution statement at the end of each manuscript. This links the video communication task back to a real-world research scenario. This could be adapted in vocation-focused courses to tasks related to the appropriate work environment.

(13) Anonymity in this context means anonymous from other students. See Top Tips below for more information on how this task facilitates student assessment.

64.5 Top Tips for New Instructors

General session implementation

If using these activities for virtual/online courses, the instructor needs to join each group for a short while to ensure students engage appropriately.

Our students reported how important it was to have these sessions as compulsory—they served as anchoring times when the groups would also discuss project progress and actions.

Session 1

Students value the first session for getting to know each other and to decide on task allocations. In a virtual environment this may be more awkward; teacher support and prompting may be more necessary online than in the classroom.

It is useful for students to exchange timetables in the first session to help them plan when they will meet and/or work together on tasks. When using Microsoft Teams they can put screenshots of their timetables in the collaboration space.

For ongoing communication, collaboration software like Microsoft Teams can help as they also have mobile apps, so students do not need to give out private phone numbers. Snapchat can also be useful (Faulkner 2018) and group chats like WhatsApp are popular (as of 2021!).

Session 2

We have used other role plays such as hypothetical situations for common problems (like social loafing). Allocate 10 min for any addition and if it is a new team assignment, start with one task and add tasks in future years based on problems noticed in the first year.

It helps to remind students that expression of emotion is not bad and can help identify problems, but that they need to step back and avoid personal attacks. A way to avoid discussions becoming personal is for students to use invitations for feedback when they present an idea or a problem, so everyone becomes more open to discussion.

Session 3

This session is often a wake-up call to students who may have been doing less or not meeting their originally-agreed tasks. It is important that there is still time after this session for those students to contribute more before the final product submission.

As part of the discussion after the individual reflection, remind everyone that they have common goals (like a good mark!), which could further strengthen the team.

Peer assessment

We have used peer assessment in two ways: (A) traditional peer marking being worth 5% of the final mark; (B) students weighted contributions to the assignment (based on Session 4; Appendices 8 and 9) and the instructor scales the final product mark according to contributions. In this second format the peer mark could affect their grade more than 5%, so it is important that students are aware this can only be applied if problems are discussed with the instructor prior to the end of the final team training session. This means students have to engage in conflict resolution (via mediation) which has proven successful in resolving minor misunderstandings and resulting in even mark distribution. This is much more beneficial for everyone as the students learn that problems are often not serious and give them confidence to tackle at least small conflicts in future.

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Further Reading/Exercises

Appendices 1–9.

Kuchel, L. J., Stevens, S. K., Wilson, R., & Cokley, J. (2014). A documentary video assignment to enhance learning in large first-year science classes. *International Journal of Innovation in Science and Mathematics Education, 22*, 48–64.

Rasmussen, A., Rossini, R., & Kuchel, L. (2011). *Is it worth taking time out of first year science courses to explicitly teach team skills?* 34th HERDSA Annual International Conference. Higher Education Research and Development Society of Australasia.

Website Links

Teaching Teams - Rasmussen lab webpage and resources. (https://www.arlab.co.uk/teaching-teams.html). *Accessed 25th Jan 2021*

Digital Education Practices - Podcast discussion of these tasks. (https://digitaleducationpractices.com/2020/06/01/episode-9-creativity-in-the-sciences-using-hybrid-online-in-person-teaching-strategies-for-resilient-education/). *Accessed 25th Jan 2021*

Faulkner 2018. (https://suzannessnapchat.wordpress.com/2018/02/27/top-10-reasons-your-students-will-thank-you-for-using-snapchat-as-a-tutorial-tool/). *Accessed 25th Jan 2021*

Student videos - project outcomes. (https://mediaspace.nottingham.ac.uk/category/Plants%20and%20the%20Soil%20Environment/166633361). *Accessed 25th Jan 2021*

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Louise Kuchel is an Associate Professor of Biology and Science Education researcher at the University of Queensland, Australia. A biologist by training and award winning teacher, Louise works on the theory and best practices for teaching science communication to scientists and science students, with her resources adopted in several countries. Louise is a Senior Fellow of the Higher Education Academy and contributor to the CLIPS website (www.clips.edu.au).

65 Making Note-Taking Memorable

Carol Oliver

Working - Investigating - Writing

65.1 Learning Outcomes

Efficient note-taking is a fundamental skill for university studies, research, and the workplace. We assume students can take notes effectively, and so it is rarely taught. This activity engages students with Cornell Notes, an organised note-taking method that exposes students to the importance of active learning. They also learn reviewing and reflecting on notes are foundational to retaining information, relating it to the patterns and structures between concepts and being able to communicate those ideas. After completing this activity, students will be able to:

1. Extract, interpret, and relate factual and conceptual information more effectively.
2. Use the Cornell Notes method to easily self-test memory.
3. Gain an active learning-driven note-taking skill for their studies, research, and eventual workplace.

65.2 Teaching Context

This activity is best taught at the outset of a course to enable active learning. It is a generic skill suitable for teaching in any subject, but especially science because of the ease of sketching diagrams and recording formulas.

I use a YouTube subject matter-related video for students (for example, storytelling, Phillips, 2017) to test their new-found skill with a low-marks assessment in

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which they submit only their Cornell Notes. The video can also be a short lecture you create. The YouTube video or lecture should be no more than 15 min.

Cornell Notes is suitable for teaching at undergraduate or postgraduate levels.

65.3 Overview of the Teaching Activity

This activity begins with an introduction to the Cornell Notes method with links to instructional videos (see weblinks below). Students discuss the introduction's content in a video conference (but this can also be in a face-to-face classroom). Students later watch a 15-min video, taking notes using the Cornell method and then submit them for marking. Electronic submission requires students to scan or take an image of each page of notes and create a PDF from the scans or pictures. The notes should be no more than two pages.

Studies show that the pen can be mightier than the laptop (Allen et al., 2020; Mueller & Oppenheimer, 2014). Students who take longhand notes out-perform the laptop note-takers in both factual and especially conceptual testing. Researchers point to laptop note-takers tending to record lectures verbatim because they can—but in doing, so they are engaged in passive learning. The lengthy notes may also make review wieldy. On the other hand, longhand note-takers have to think and make abbreviated notes in their own words (active learning) because handwriting takes longer. However, the notes are easier to review and reflect on regularly, allowing the transfer of the content to long-term memory, which in turn helps students make more sense of the links between concepts. Many universities encourage the use of the Cornell Notes method, which Cornell University education Professor Walter Pauk developed in the 1950s for his book *How to Study at College*.

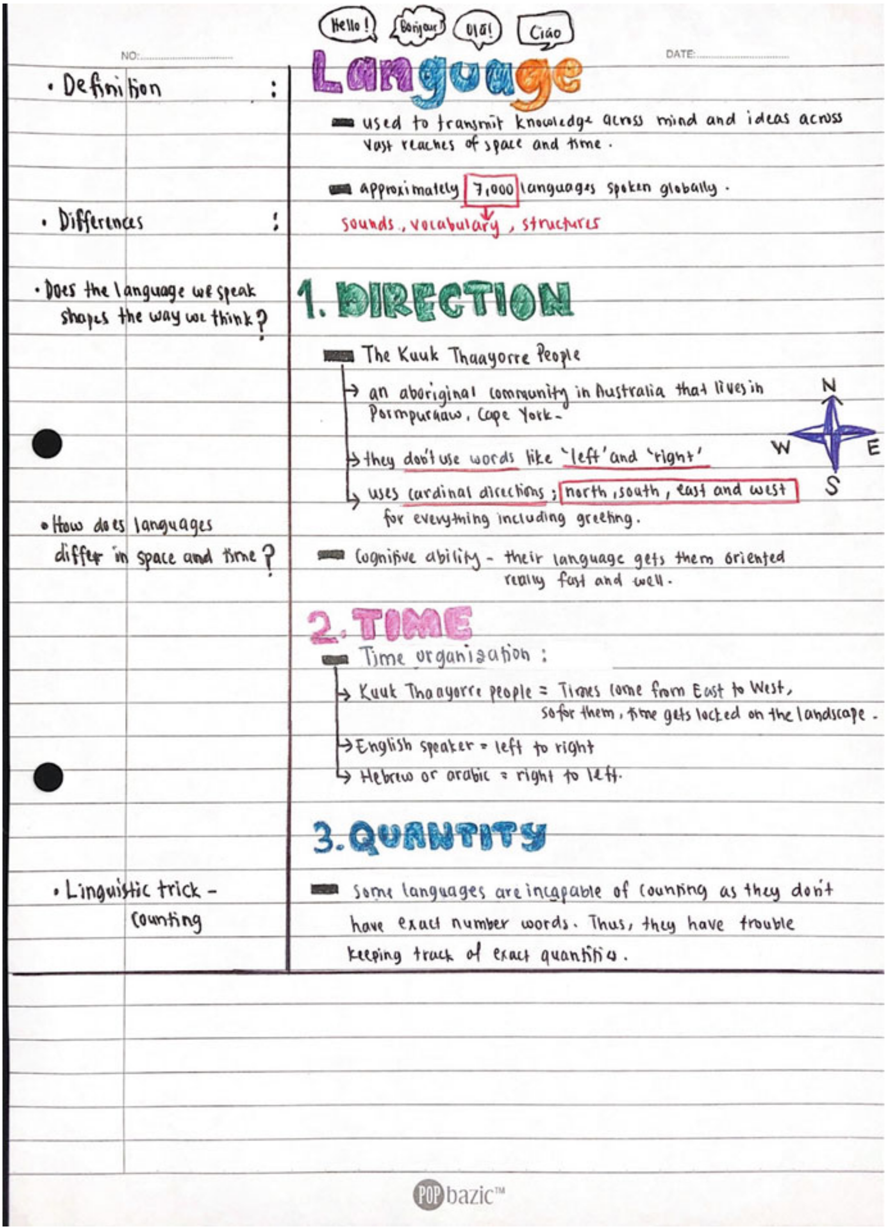
65.4 Runsheet and Lesson Plan

Cornell Notes has five Rs that make the method particularly useful for students in learning: Record, Reduce, Recite, Reflect, and Review. These emphasise that the act of note-taking does not end when the lecture, video, or research are over. There are four phases as Claire Brown points out in her article on Cornell Notes in The Conversation (additional reading 1 below): The note-taking, the note-making, note interacting, and note reflecting—all accounted for in the Cornell Notes five Rs:

1. **Record:** In the note-taking column using abbreviated dot-points; encourage students to develop suitable shorthand (e.g. plus symbol to link ideas together).

2. **Reduce:** As soon after listening to a lecture or watching a video, create cues and questions in the left-hand column to clarify and relate content, and to strengthen memory.
3. **Recite:** Cover the note-taking column, or fold the paper, to recite back what the cues mean or to answer the questions aloud.
4. **Reflect:** The student asks questions of himself or herself, such as "What is the meaning of this lecture (video)?" and "How can the information be applied?"
5. **Review:** The student reviews the notes for 10 or 15 min each week to transfer to long-term memory (see the Ebbinghaus forgetting curve further reading 1).

The most effective strategy is to introduce this activity in Week 1, which also allows for feedback to the student early in the course. Making the short Cornell Notes assessment low-stakes in terms of marks seems sufficient to get all students to submit. Relate the video students use to the subject matter of the course. Here is an example of notes taken by one of my students, and the video I used is here (https://www.youtube.com/watch?v=RKK7wGAYP6k).


Hello! Bonjour! Olá! Ciáo

NO: DATE:

Language

• Definition :
- used to transmit knowledge across mind and ideas across vast reaches of space and time.
- approximately 7,000 languages spoken globally.

• Differences :
sounds, vocabulary, structures

• Does the language we speak shapes the way we think?

1. DIRECTION
- The Kuuk Thaayorre People
  → an aboriginal community in Australia that lives in Pormpuraaw, Cape York.
  → they don't use words like 'left' and 'right'
  → uses cardinal directions ; north, south, east and west for everything including greeting.

N W E S

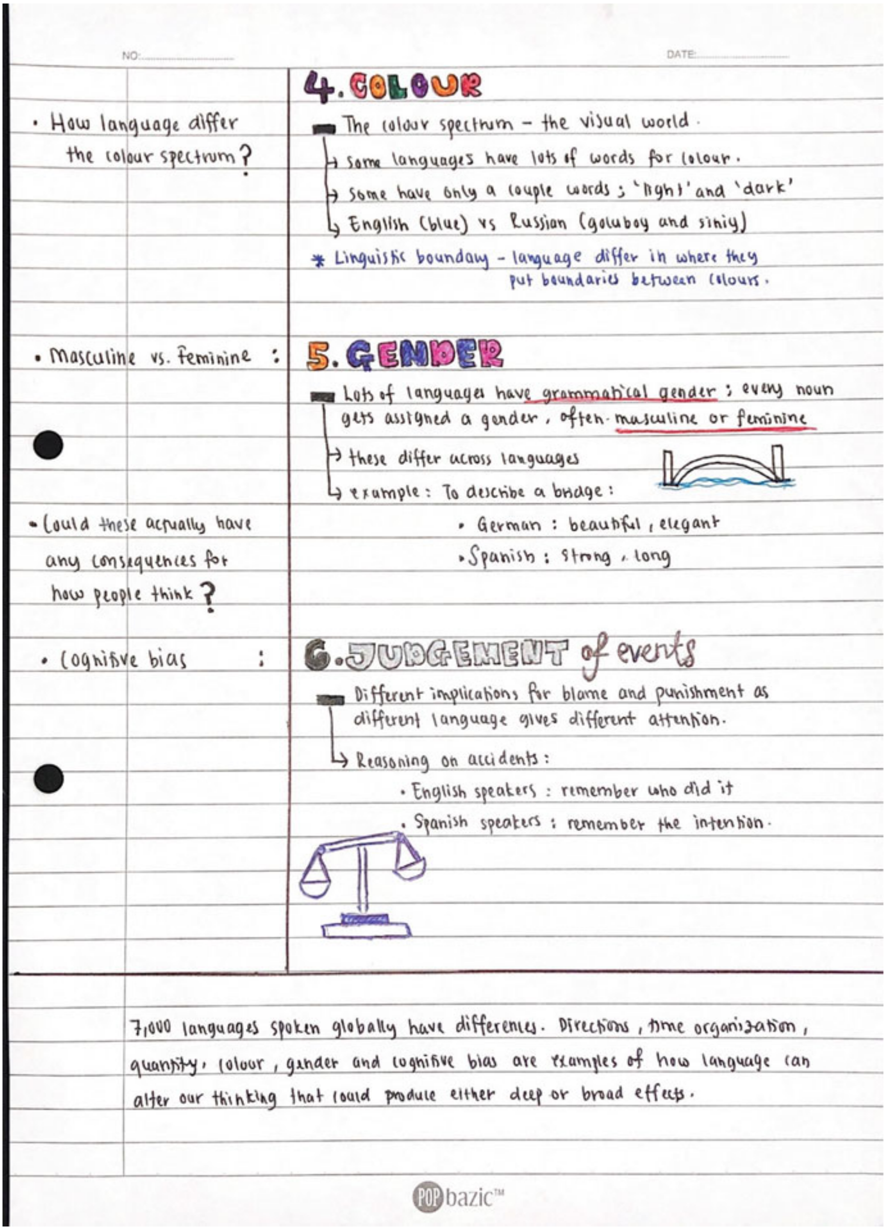
• How does languages differ in space and time?
- Cognitive ability - their language gets them oriented really fast and well.

2. TIME
- Time organisation :
  → Kuuk Thaayorre people = Times come from East to West, so for them, time gets locked on the landscape.
  → English speaker = left to right
  → Hebrew or arabic = right to left.

3. QUANTITY

• Linguistic trick - counting
- some languages are incapable of counting as they don't have exact number words. Thus, they have trouble keeping track of exact quantities.

POP bazic™


NO: DATE:

• How language differ the colour spectrum?

4. COLOUR

The colour spectrum – the visual world.
↳ Some languages have lots of words for colour.
↳ Some have only a couple words; 'light' and 'dark'
↳ English (blue) vs Russian (goluboy and siniy)

* Linguistic boundary – language differ in where they put boundaries between colours.

• Masculine vs. feminine:

5. GENDER

Lots of languages have grammatical gender; every noun gets assigned a gender, often masculine or feminine
↳ these differ across languages
↳ example: To describe a bridge:
• German: beautiful, elegant
• Spanish: strong, long

• Could these actually have any consequences for how people think?

• Cognitive bias:

6. JUDGEMENT of events

Different implications for blame and punishment as different language gives different attention.
↳ Reasoning on accidents:
• English speakers: remember who did it
• Spanish speakers: remember the intention.

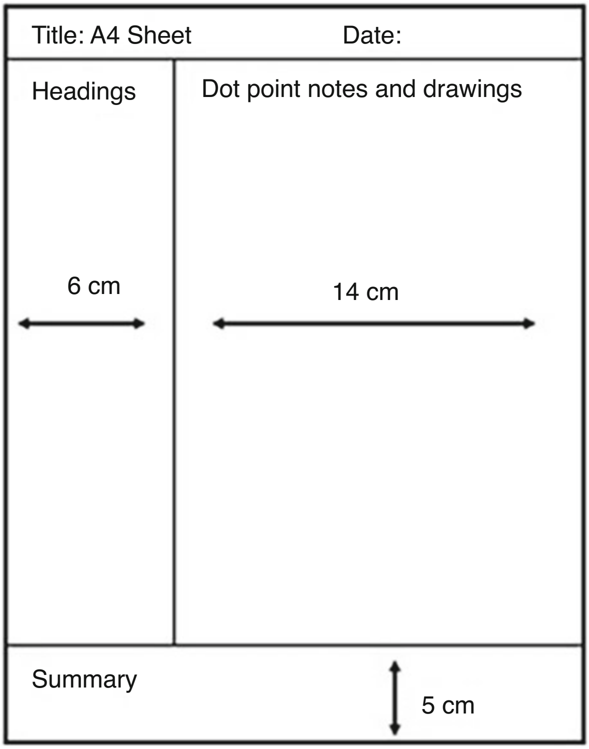
7,000 languages spoken globally have differences. Directions, time organization, quantity, colour, gender and cognitive bias are examples of how language can alter our thinking that could produce either deep or broad effects.

POP bazic™

You can create the Cornell Notes layout in the following way:

1. Divide an A4 (or letter size) lecture pad sheet into four with two horizontal rules and one vertical.

2. The top horizontal line leaves enough room for the title and date at the top. The lower horizontal line leaves about 5 cm for the summary at the bottom of the pages
3. Split the bulk of the page vertically between the two horizontal lines—about 25% for a left-hand column to list the cues or questions and the remainder on the right for the abbreviated notes synthesis and drawings shown in the below image.
4. Note in the resources below that a template for Word or PDF for printing out is also available.



Select a relevant video of no more than 15 min. Fill in the Cornell Notes sheet with cues on the left-hand side and abbreviated notes on the right-hand side and a summary at the bottom as example notes—or use the one I provide. Choose another video of no more than 15 min for the assignment or use the Phillips storytelling video (in the references). Now you are ready to begin.

Instructor does…	Students do…	Resources
Prepare instructions on the five Rs (given above), include example notes the video from which the notes were taken. Select from the short explanatory Cornell University videos (weblinks below) and add to instructions content. Enter into the appropriate week of your course in the Learning Management System (LMS).	View instructions, example notes and video, and Cornell Notes instructional videos in preparation for the class.	Cornell Notes instructions with example notes and video; Cornell Notes instruction videos 30 min
Prepare assessment instructions and rubric (see Tips for example). Select a 15-minute video of your lecture or a YouTube video and provide a link to Cornell Notes layout for students to print out.		Cornell Notes layout template (1); 15-minute video of your choice 15 min
Run the tutorial and discuss: • the purpose of note-taking; • the Cornell Notes method's elements; • studies that show students do better in tests if they use longhand rather than typewritten notes. • the five Rs. • the features of taking abbreviated notes, creating cues or questions, and making a summary of each page after the note-taking event.	Come prepared with template (1). Participate in class discussion.	See reference links to some studies below. Whiteboard or electronic method to discuss and model note-taking. 30 min
Review assessment rubric for Cornell Notes assessment with students.	Create their Cornell Notes and submit them.	Video from your lecture or YouTube; Assessment instructions 30 min
Total duration in-class = 30 min + 30 mins for students to undertake assessment		

Notes

(1) The Cornell Notes template is drawn in an ordinary notebook. An alternative is downloading a template from here: https://www.timeatlas.com/cornell-note-template/ in Word or PDF format and print out. Or Cornell notebooks are available at various sellers including www.amazon.com.au.

(2) Cornell Notes are best formed on A4 (or Letter size) lecture pads and put into ring binders. The binder method allows access to a single page of notes, which the student can extract, fold on the left-hand cues column, and test their recall of the notes when revising.

(3) Students take an image or scan their notes and save as a PDF to upload to an electronic repository. If your university uses Turnitin, have students create the Word document to insert at least 20 words so Turnitin will recognise the PDF.

(4) There is little data on whether using a digital smart pad and pen has the same benefits as longhand in note-taking. A digital pen allows freehand drawing and colouring. However, the folding benefit of (2) above would not apply.

(5) There are other formats of taking notes, employing active learning and typically done in longhand, such as the outline, charting, and mapping methods. However, Cornell Notes has no limiting disadvantages while having the built-in advantage of using the cue column for self-testing.

65.5 Top Tips for New Instructors

I award full marks where students have successfully interpreted the use of Cornell Notes. It will be easy to see the variation from poor to excellent note-taking. I have noted some relationship between the marks for the Cornell Notes assessment and the overall grade a student achieves in the course.

Seek feedback from your students on the Cornell Notes assessment. I use opportunities like sending an email to students saying how well they have done or how they can improve and ask them what they thought and whether they learned—and what they learned—from the assessment. Feedback enables me to improve on providing precisely the right scaffolding students need to grasp the Cornell Notes method.

Talk to your students about learning to learn—and more precisely, how to transfer learning into long-term memory. One of the Cornell Notes benefits is the ease of review—just 10 min a week is sufficient. German psychologist Herman Ebbinghaus demonstrated the effectiveness of regular revision in 1895, which he called the forgetting curve. For the diagram, see Brown's Conversation piece in the first of the additional reading below.

Be prepared for students to express surprise when the first part of the first assignment requires just a copy of their handwritten notes using the Cornell Notes method. However, students report using the technique subsequently both for my course and in other subjects.

References

Allen, M., LeFebvre, L., LeFebvre, L., & Bourhis, J. (2020). Is the pencil mightier than the keyboard? A meta-analysis comparing the method of note-taking outcomes. *Southern Communication Journal, 85*(3), 143–154.
Mueller, P. A., & Oppenheimer, D. M. (2014). The pen is mightier than the keyboard: Advantages of longhand over laptop note-taking. *Psychological Science, 25*(6), 1159–1168.
Phillips, D. (2017). *The magical science of storytelling*. TEDxStockholm. Accessed May 2, 2021, from https://www.youtube.com/watch?v=Nj-hdQMa3uA

Additional Reading

The Conversation (1). (2015). *What's the best most effective way to take notes?* https://theconversation.com/whats-the-best-most-effective-way-to-take-notes-41961
The Conversation (2). (2020). *Note-taking by hand: A powerful tool to support memory*. https://theconversation.com/note-taking-by-hand-a-powerful-tool-to-support-memory-144049

Website Links

Sacramento City College Cornell Notes instructional video. (https://www.youtube.com/watch?v=lsR-10piMp4). *Accessed 5 Jan 2021*.
Cornell University note-taking instructional videos, Video 1 (https://www.youtube.com/watch?v=HEsBd_Rgzfs) and Video 2 (https://www.youtube.com/watch?v=nX-xshA_0m8). *Accessed 3 Jan 2021*

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My Favourite No: How to Critique the Reasoning of Others

66

Holly Garrett Anthony and Kelly Moore

Working - Engaging - Distilling

66.1 Learning Outcomes

Students often struggle to articulate what they do and do not understand, particularly in the sciences. Intimidated by the specialized vocabulary and hesitant for their instructor and peers to discover their knowledge deficits, students pass on opportunities to share their thinking and their work. Yet, discussing understanding (or a lack thereof) is a key skill in study and in the workplace. Being able to accept and reflect on feedback, and being able to give constructive critique of others' work, are also key workplace skills.

This formative assessment activity invites students to share their work publicly (without fear of embarrassment or reproach), to accept and reflect on feedback, and to constructively critique the reasoning of their peers.

In this activity, students confront the common mistakes in their work (and the work of their peers). The instructor models and invites constructive critique and discussion as part of the activity. By the end of the activity, students will be practised in accepting, reflecting on, and acting on feedback. They will be able to clearly articulate both their strengths and the areas in which they can improve.

66.2 Teaching Context

We typically use this technique to review mathematics homework, but it is broadly applicable to any context in which students solve problems that require step-by-step solution paths. This activity is suitable for both undergraduate and graduate level

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classes, for all maths and science disciplines, and it can be incorporated regularly or intermittently within a course. Regular implementation of this technique fosters a classroom culture akin to a professional learning community in which students become comfortable making mistakes, offering constructive critique, and learning from giving and receiving feedback. As noted above, these are key workplace and study skills.

We recommend this technique for lessons or problem sets in which students' common mistakes tend to emerge. By showcasing students' solutions anonymously and facilitating a class discussion of the instructor's "favourite no"—or favourite wrong answer—students can articulate what they know and do not know. As a result they become more able to self-remediate their areas of confusion. This technique also provides an open and inviting platform for students to learn how to productively critique the reasoning of others without singling out any particular student or students.

This exercise focuses on common misconceptions in students' work. In science instruction, student misconceptions are typically resilient and persistent (National Research Council, 1997). In order to correct a misconception, students must engage in a process where they experience a tension around their currently-held beliefs. This requires that the teacher identify student misconceptions, provide a way for students to confront their misconceptions, and then help students reconstruct their understanding to fit the corrected information.

Through this activity, teachers are providing the first two steps of this process. First, they gather student responses to categorize any misconceptions. Second, they present the "favourite no" to the class which engages the students in a productive critique activity while they process why the "favourite no" is incorrect. Students must confront their own misconceptions as they work through analysing the "favourite no". This then positions students for the third step of incorporating the new, correct information into their knowledge base.

The activity is conceived as an opening activity to launch a lesson, but it could be reconceived as a closing activity where the index cards are collected at the end of a lesson, sorted by the instructor in the interim, and discussed at the beginning of the subsequent class meeting.

66.3 Overview of the Teaching Activity

The activity begins by either selecting a problem from the previous lesson's assignment, or by providing a problem for students to complete within the first few minutes of class. Students are asked to write their solution steps (showing all work) on an index card. Students do not include their name or any other identifying information.

After a predetermined amount of time (5 min or less is recommended), the instructor collects all of the index cards and quickly sorts them into groups. Initially, the instructor will sort the problems into two categories: correct and incorrect. The instructor then revisits the stack of incorrect solutions and looks for natural groupings related to the error patterns that he/she sees. It is important to identify problems that showcase correct applications of mathematical thinking and/or equations, but in which a mistake has led to an incorrect solution. The goal is to select your "favourite no"—or your favourite wrong answer—so you can use that work as a launchpad for a classroom discussion in which students critique the featured solution. To further ensure anonymity of the student whose solution is to be discussed, the instructor should rewrite the student's work in its entirety in his/her own handwriting to prevent the chance identification of someone's script.

The "favourite no" is then made public via a document camera or tablet. If the instructor has chosen the problem carefully, it should be representative of the thinking of several students in the class. Students then engage in a public critique of the problem with guided questions from the instructor to facilitate the discussion.

The instructor models good critique practice—critique should first highlight what has been done well and then move into a discussion of the mistake and how it should be repaired. Ask: "What do I like about this problem? What has this student done correctly?" After that discussion concludes, ask "What is the mistake in this problem? What was done incorrectly?" Also ask "How can we fix this error? What thinking can we use to help us?"

The end goal of the critique is twofold. The first aim is that students identify the error, recognize whether they made this error, reflect on how and why they made the error, and use the immediate feedback to correct their work. The second aim is that students hone their communication skills with regard to verbal critique and discussion. These skills of critique, discussion, and reflective correction of mistakes are essential in the modern science workplace.

66.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Provide a problem (1)	Work the problem on an index card showing all steps/work	Problem Index Cards for student 5 min
Collect the index cards and sort them into categories (2)	Submit index cards and self-reflect on their solution	3 min
Identify "my favourite no" (3). Rewrite it to share with the class (4)	Review the "favourite no" and consider what is correct/incorrect	Document camera or tablet for facilitator 2 min
Facilitate discussion (5)	Critique/discuss the "favourite no" What was done well? What was the mistake?	5-7 min
Extension Prompt students to summarize the discussion in writing (6)	*Extension* Write a note to a friend identifying the mistake and explaining how to correct it.	Exit Ticket or Journal Prompt 3 min
Total duration in-class = 15 min + 3 minute in-class extension		

Notes

(1) The problem should be related to the content or methods from a previous lesson or assignment.

(2) Initially, sort the problems into two categories: correct and incorrect. Revisit the stack of incorrect solutions and group by error patterns.

(3) Identify your "favourite no"—one that showcases correct applications of the disciplinary thinking and/or methods, but which features a mistake has led to an incorrect solution. It should represent a mistake you observe across multiple students.

(4) Rewrite your "favourite no" in its entirety in your own handwriting to prevent the chance identification of someone's script. Make it public to the class via document camera or tablet.

(5) Model constructive criticism and respectful dialogue. Make it clear to students that this is what you are doing, and this is a skill you would like them to learn. Ask: "What do I like about this problem? What has this student done correctly?" "What is the mistake in this problem? What was done incorrectly?" Solicit multiple perspectives from several students. Students should take the lead, not the instructor. Encourage and reward respectful language and questioning practice from the students.
(6) This could be collected as an Exit Ticket at the end of class or could be in the form of a journal/notebook prompt.

66.5 Top Tips for New Instructors

1. As instructors become more familiar with their course content and their previous students' work, it is easier to anticipate and locate the common errors that are often repeated across different groups of students in each iteration of the course. This will decrease the overall implementation time to 10 min or less.
2. Students will be reluctant to share their critique publicly in the first few iterations. Be patient and encouraging. Continue to prompt with questions and allow them to develop their critique without instructor input. Students should identify the strengths of the problem and the mistake. If the instructor becomes impatient and offers this instead, it will be difficult to generate deeper discussion later.
3. Students enjoy the culture of a classroom in which "it is okay" to make mistakes and learn from them. But, developing this culture must be intentional on the instructor's part. Share your goals for the activity with the students so they know what you are seeking to accomplish: a safe space to discuss/critique reasoning and learn from each other about how to do critique and how to solve the disciplinary problems you are discussing.
4. The video, *My Favorite No* (produced by The Teaching Channel, USA) provides an overview for how to facilitate the activity.
5. You may want to use sentence scaffolds and question prompts to help students critique each other's work (See Chap. X).

Reference

National Research Council. (1997). *Science teaching reconsidered: A handbook*. The National Academies Press. https://doi.org/10.17226/5287

Website Link

My Favorite No. (https://www.youtube.com/watch?v=srJWx7P6uLE). *Accessed 21 Jan 2021*

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Understanding and Articulating Your Employability as a Science Graduate

67

Bonnie McBain, Liam Phelan, Dawn Bennett, and Elizabeth Bronwen Knight

Working - Intent - Investigating

67.1 Learning Outcomes

After completing this exercise, students will be better able to recognise the skills and attributes they develop within and beyond their formal education, and to articulate these skills and attributes to prospective employers and placement hosts. In this activity students begin to recognise their skills and attributes with the support of an online self-reflection tool. Through the reflective process, students also begin to understand that oral communication skills are important for articulating their employability—and that being concise, clear, and evidence-based is key to their success.

Students demonstrate their learning through an authentic assessment task—in this case, a video elevator pitch. The task is authentic in that students can share it directly with prospective employers. The video pitch can stand alone or complement written communication with prospective employers. More broadly, the brief video pitch is suitable for building professional networks, for example, through students posting on social media about their career interests and skills.

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67.2 Teaching Context

Science students' capacity to communicate their skills and attributes to employers, placement hosts, and through their professional networks is key to their success in gaining professional experience during their studies and employment upon graduation. However, few degrees explicitly teach these skills as part of disciplinary learning. We note also that recent policy attention on teaching quality in many countries equates education quality with the employment rates of graduates. This alignment is both simplistic and problematic. Nevertheless, it means that a focus on graduates being able to communicate their employability is important for universities.

Evaluation of qualitative student feedback data indicates that many science students:

- are unaware of many of the opportunities they have to develop skills;
- are unaware of many of the skills they have already developed;
- are unaware of the skills employers seek; and
- report a lack of confidence and high levels of discomfort using oral communications techniques.

Given appropriate support, students can successfully increase their awareness of the skills and attributes they develop through their studies. They can also improve their ability and confidence in communicating their skills and attributes.

In this teaching activity students use an online employABILITY tool (Bennett, 2019) to create a 29-page personalised employability profile. The engagement with the profile is critical in setting context for students and supporting their understanding of employability. The profile helps students articulate their own employability, and is used in partnership with the video elevator pitch assessment task.

It takes time for students to build their employability, just as it takes time to build other capabilities. Including this activity early in a programme of study gives students time to learn, practise, and refine before graduation.

We recommend properly integrating this learning activity into curriculum, rather than presenting it as an 'optional extra'. Doing so lends the activity legitimacy in the eyes of students, who may not appreciate its value until after completion.

67.3 Overview of the Teaching Activity

This activity requires students to make several short (1-min) videos in which they communicate their career aspirations, values, and skills (i.e. an elevator pitch). Students complete up to five practice iterations. Interaction helps students (1) become comfortable using hardware and software; (2) become familiar with recording and watching their own recording; and (3) self-assess their work. Students are invited (but not obliged) to share their practice recordings with peers or the tutor if they wish to receive formative feedback. Finally, students record a 1-min elevator pitch and submit this as an assessment task for summative feedback.

These iterations can be spread over several weeks or across a full day of intensive activity. The key is that students have multiple opportunities to engage in a 'do, evaluate, revise and repeat' cycle.

This activity was originally designed for a blended course with most of the content communicated to students online followed by highly collaborative and participatory workshops to deepen and apply the online learning. The activity can be adapted to other learning modes (on campus and online). In the lesson plan that follows, we have assumed that the activity runs over several weeks and that initial instructions are online.

The content of the pitch will vary depending on the discipline. The Developing Employability website provides content-related resources for both educators and students for all disciplines and for science specifically (link below).

67.4 Runsheet and Lesson Plan

Instructor does…	Students do…	Resources
Part 1: Preparation and context		
Introduce the Employability Profile (1)	Complete the Employability Profile online (2)	*'Six step process'* See link 3
Provide an overview of the assessment task	Become familiar with the assessment task components	Assessment task description
Explain why the activity is relevant for students' future employment (2)	Reflect on their profile results so they are aware of what employers seek and what they can highlight in their pitch.	Employability profile
Part 2: During the session		
Introduce the speaking activity and explain how to create an elevator pitch. Explain the iterative nature of the exercise (3) (4) Clarify the students' audiences (5) Clarify any task constraints (6)	Ask clarifying questions as needed	*'How to create an elevator pitch'* See link 5

Instructor does…	Students do…	Resources
Provide examples for students	Review examples	*'Me in a Minute'* See link 4
Provide instructions for students to familiarise themselves with software and hardware as necessary (7)	Practice using the software and hardware	Devices and software from university or students. Online access.
Encourage students to write their scripts	Students design their script	*'How to create and elevator pitch'* See link 5
Part 3: Practices, feedback opportunities, and assessment		
Workshop activity giving peer feedback on script or pitch	Students read their pitch script or present their	Example description of proficiency for
	pitch to a peer. Peer provides formative feedback	use as benchmark (8).
Part 3: Practices, feedback opportunities, and assessment		
Provide information on how students can receive formative feedback on their assessment and what sort of summative feedback they will receive	Review assessment task description and optionally send link of presentation to instructor for formative feedback	Example description of proficiency (8)
Students record 5 practice hurdle task recordings.	Submit five hurdle task recordings.	Submission portal.
Final assessment submission	Last pitch recorded and submitted for assessment	Submission portal.

Notes

(1) Completing the Employability Profile allows students to better understand the concept of employability and their own developing employability.

(2) Give students a link to the employABILITY tools in their learning management system.

(3) Students can find it difficult to talk about themselves meaningfully and concisely. With practise it becomes easier. The activity's iterative structure without allocated marks gives students many low stakes opportunities to practise.
(4) Our experience is that making each practice opportunity a hurdle task (i.e. task completion is required to pass, but no grades are allocated) is useful; it gives students the opportunity to make mistakes and learn through them. Any 'mistakes' in early practice videos are learning opportunities. The hurdle tasks are a safe space for students to practise. The recordings are private because they are not accessed by the tutor unless the student specifically asks for formative feedback. It helps to talk about 'mistakes' in early videos using the analogy of scientific discovery. That is, the key to success is rigour, and finding and then amending a 'mistake' in a video pitch is improvement and refinement, rather than failure.
(5) The primary audience for this video is prospective employers.
(6) Examples of useful constraints include (1) no PowerPoint; (2) maximum video length of 1 min; (3) props may be used but are not essential.
(7) Although students are tech-savvy, they can get confused about how to make and upload a video. The instructions need to be very clear and upload or link-sharing methods should be tested on your university platforms to ensure they work. Students can use free or paid software to record their material (or they can just film themselves on their phone). Students can upload their videos to an external online platform or to your university learning management system (LMSs). Talk with your students about the easiest way for them to create and share content. They will have some great ideas. Be aware that not all students have a good phone for filming. You may need to place them in small groups so they can share resources and film each other. Pedwell et al. (2018) includes useful instructions on how to produce good recordings.
(8) The following description of proficiency can be customised to form a marking rubric for your teaching purposes:

Criterion	Description
Passion	Information presented is relevant and clearly supports the aspiration towards career and/or life goals. The presentation provides a convincing picture of the student's passions for applying their training.
Skills	Speaker identifies their abilities with relevant examples of three graduate capabilities sought in the workforce.
Evidence	Appropriate evidence is provided to justify claims of skills and attributes.
Elocution (speech)	Speaker engages the audience by using the following strategies: speaks clearly; speaks at a natural pace; shows enthusiasm; demonstrates confidence without arrogance; varies pace/tone naturally for emphasis; uses professional language.

Criterion	Description
Visual	All of the following occur: The background is plain and professional and does not distract from the presentation; the speaker makes eye contact with the camera and does not read notes; hands are out of screen or not moving; the speaker smiles at appropriate times.
Flow	Ideas are logically organised: introduction gives clear overview; conclusion summarises succinctly. Audience has clear understanding of key points and argument as a whole.

67.5 Top Tips for New Instructors

1. Some students feel very vulnerable making their pitch. Keep your feedback encouraging and constructive. Supportive feedback can be provided as per the hamburger or praise-question-polish feedback model. Begin with commendation, then give a recommendation or ask a question. Finish with a further commendation or polishing comment.
2. Students will be more confident doing this activity if you provide multiple opportunities to receive feedback (although, do not be surprised if only a few students ask for feedback). Repeatedly mention opportunities for feedback.

References

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Website Links

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Employability resources for STEM students. (https://developingemployability.edu.au/toolkit/#STEM-toolkit). *Accessed 13 Dec 2022*.

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How to Conduct Elicitation Interviews with Clients

68

Radhika Jaidev

Working - Intent - Listening

68.1 Learning Outcomes

In this workshop, students learn how to prepare for and use effective questioning and listening strategies to understand the needs of others.

68.2 Teaching Context

In this workshop, students learn how to inhabit the role of vendor (and problem solver) for a client who has a problem or need. Students learn how to prepare for a vendor–client interview, how to question to understand a client's needs, and how to listen actively. I run this workshop with software engineering students just before they begin a collaborative project with a host company. In an accompanying workshop (not described here) we test the students' learning through a vendor–client role-play.

We use a software requirements-elicitation interview as a context for the information-gathering approaches taught in this workshop, but any process in which a person is trying to understand a client's needs would be appropriate. This approach could be useful in many different situations (e.g. an organisation wanting information on the environmental effects of their business; a hospital wanting diagnostic services; a client wanting a new chemical synthesised; a food company wanting a new texturising food additive).

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68.3 Overview of the Teaching Activity

Initially, students think about and discuss different ways in which they could gather information on a client's needs (e.g. brainstorming, focus group, community consultation, document analysis, focused interviews, and observation). Students share the advantages and disadvantages of each information-gathering method and consider the point in the requirements-elicitation process where each method could be used. Students who have real work experience are invited to talk about their vendor–client information-gathering interactions and any challenges they faced in those situations.

We then show a 5-min video on the four-step process for requirements-elicitation and ask students to complete a task sheet (Appendix 1) on the best practices shared by the video. From this, students learn about the importance of preparing in advance of a vendor–client interview.

After this, students learn about effective questioning techniques and active listening and how these are both equally important in an elicitation interview. A good introduction to questioning techniques is to use the 5Ws1H. These are *Who, What, Why, Where, When*, and *How* (see Resources, especially Resource 3). This is followed by a role-play with a real problem scenario.

68.4 Runsheet and Lesson Plan

It is best to limit the class to 20 students. The Appendices given in this table were developed by the author. The Resources given are examples of freely-available online materials you could choose to incorporate as supports for your students.

Instructor does…	Students do…	Resources
Get students into small groups (3-4) and brainstorm different ways to gather information when addressing a problem (including strengths and weaknesses for methods).	Offer suggestions for methods and for pros and cons of each method.	Resource 1 10 min
Invite students who have work experience to discuss a time when they gathered information on the needs of another party (client). Sum up key points about requirements elicitation (1).	Students who have worked before share their experiences.	Students who have work experience 10 min

Instructor does…	Students do…	Resources
Show 5-min video on the 4-step requirements-elicitation interview process. Give students the task sheet to guide their viewing and help them capture essential points.	Watch the video and complete the task sheet.	Resource 2 and Task Sheet (Appendix 1) 15 min
Introduce students to key aspects of good interview questioning including (i) Use of open-ended and closed question - open-ended to probe for information and closed to confirm and validate information. (ii) Use of the 5W 1H framework.	Pose suggestions for the types of questions that fit into each category.	Resources 3, 4, 5 & 6
Introduce idea of body language – open listening posture, closed posture	Practice postures	Resources 7 and 8 15 min
Introduce idea of active listening. Include practices listeners can use to listen actively.	Practice active listening	Resources 9 and 10 15 min
Introduce the role play activity where students work in pairs on a real-life, elicitation interview scenario (2). Encourage students to use their notes from the class so far to guide them in their planning and role-play	Choose their scenario and plan the questions they want to ask to gather information.	Scenarios (2) 20 min
Invite students to begin their elicitation interview role-plays. Walk around, listen, observe and make notes on what students are doing noting weak and strong practices for later feedback.	Conduct their role play, with one student as "client" and one as "vendor".	Resources 1 through 10 20 min

Instructor does…	Students do…	Resources
In collaboration with the class, discuss your and their observations of how the role-playing worked. If there is a grading rubric for later assessment of the role plays (4), explain how to interpret it and how to do well against the stated criteria.	Comment on their own and their partner's work, describing strengths and weaknesses. Discuss how to improve.	Elicitation Interview assessment rubric (4) 10 min
Total duration in-class = 150 min [+ 30 mins]		

Notes

(1) Key points:
   (a) Prepare yourself by finding out as much as possible about the company's functions, products, services.
   (b) Prepare an interview brief with key questions that will help you to scope the project—these could be a mixture of open-ended questions (e.g. Tell me about the methods you use now) to more closed-ended questions that may help you to get specific answers (e.g. What is the capacity of the current system?). Be flexible and prepare to ask probing questions to get more detailed information.
   (c) Do not be in a hurry and rush the client—the context should be as relaxed as possible—you are trying to build a healthy client–vendor relationship here. Give the client adequate opportunity to ask you questions—do not be afraid to say you do not know but that you will find out and get back to her.
   (d) Ensure that you take notes or ask permission to record the interview.
   (e) Remember to sum up what was discussed—especially about the deliverables.

(2) Use a limited number of information-seeking scenarios and let students choose the one of interest. Make sure each scenario has a specific problem to solve and the client has a specific need. Ideally, limit the number of scenarios to just two, so that the open class role-play and ensuing discussion and summing up of key learning points is manageable within the allocated time.
   Examples of scenarios could be:
   (a) a school administration system is fragmented; information on students, staff, and facilities are all stored on different platforms. The school administrators would like to bring everything together in one platform.
   (b) due to community concern about climate change, a government department is looking to build a plan to manage a local wetland.
   Give students 15 min to prepare, after which they begin their elicitation interview role-play. Let students know that you will be walking around and listening in to their role-plays.

(3) Students who play the role of the "vendor" should use different question types, active listening, and positive body language when they speak with the "client". The vendor should demonstrate a genuine interest in understanding, scoping, and helping to solve the problem. The client (who has not really been coached during this lead-up) will need to be a bit creative as they answer the questions.
(4) See Appendix 2: Interview Grading Rubric

68.5 Top Tips for New Instructors

1. Flipped pedagogy, where the reading materials are put online so students can read the essential information before coming to class, works well in this workshop. The workshop described here is usually followed up with the assessment the next week.
2. Science students may initially feel that they do not need to know how to interview and communicate with clients to be successful in their future working life. This workshop helps them realise that this assumption could be a misconception! It also helps them develop discussion skills that will be useful in other situations such as group work or Work-Integrated Learning.

Website Links

Resource 1 Top 10 Most Common Requirements Elicitation Techniques. (https://www.softwaretestinghelp.com/requirements-elicitation-techniques/). *Accessed 15 March, 2021.*

Resource 2 Improve Your Requirements Elicitation Interviews with this 4-Step Process. (https://www.youtube.com/watch?v=2WBef84bodc&t=81s). *Accessed 15 March, 2021.*

Resource 3 5Ws 1H A technique to improve Project Management Efficiencies. (https://www.ipma.world/5ws-1h-a-technique-to-improve-project-management-efficiencies/). *Accessed 15 March, 2021.*

Resource 4 Questioning Techniques. (https://www.mindtools.com/pages/article/newTMC_88.htm). *Accessed 15 March, 2021.*

Resource 5 10 Effective Questioning and Probing Techniques for Customer Service. (https://www.callcentrehelper.com/practical-tips-for-effective-questioning-techniques-9045.htm). *Accessed 15 March 2021.*

Resource 6 What questions do I ask during Requirements Elicitation. (https://www.bridging-the-gap.com/what-questions-do-i-ask-during-requirements-elicitation/. *Accessed 15 March, 2021.*

Resource 7 Body Language. (https://www.mindtools.com/pages/article/Body_Language.htm). *Accessed 15 March 2021.*

Resource 8 8 Body language tips that can make or break your customer service. (https://blog.hubspot.com/service/body-language-in-customer-service). *Accessed 15 March, 2021.*

Resource 9 Important Active Listening Skills and Techniques. (https://www.thebalancecareers.com/active-listening-skills-with-examples-2059684). *Accessed 15 March 2021*.

Resource 10 The 4 steps for active listening and 10 tips for interactive listening. (https://mgrush.com/blog/active-listening/). *Accessed 15 March 2021*.

Appendix 1: Interview Preparation Task Sheet

<table>
<tr>
<td>Prepare
1. Select a __________
2. Schedule the _____ and place
3. Define the _________ of the meeting
4. Identify 5–7 questions to uncover the stakeholder's _______
5. Confirm that the questions are ________
6. Send an ___________ to the stakeholder, with the list of questions
7. Contact the stakeholder to ________ the meeting.</td>
<td>Conduct
1. Arrive on _______
2. Build _________
3. Confirm _______ of the meeting
4. Avoid ___________
5. Be polite and at _____
6. Listen ___________
7. Ask ___________
8. Summarise _____ points</td>
</tr>
<tr>
<td colspan="2">Document
Write the ________of the requirements as discussed and send it to the interviewee
Confirm
1. Ask the stakeholder for _______
2. Implement the ___________
3. Use the interview findings for requirements ___________
What did you discover about your current practice in eliciting requirements and the four steps outlined above?</td>
</tr>
</table>

Appendix 2: Example Interview Grading Rubric

Name of student:____________________________

Items	1	2	3	4	5	Notes
Body language						
States the purpose of interview						
Explains scope of the project						
Orders the questions logically						

Items	1	2	3	4	5	Notes
Probes for clarification						
Provides possible alternatives						
Sums up information gathered and seeks confirmation						
Explains ensuing process of work to client						
Closes the meeting politely						

1—Poor/5—Excellent

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S. Rowland, L. Kuchel (eds.), *Teaching Science Students to Communicate: A Practical Guide*, https://doi.org/10.1007/978-3-030-91628-2