USING EXPERIENTIAL LEARNING TO HELP UNDERGRADUATES UNDERSTAND THE SCIENCE OF SCIENCE COMMUNICATION

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Abstract

Experiential learning is a high-impact practice in education, but there are few examples of how to implement experiential learning in the undergraduate communication classroom to advance skills in science communication and expose students to scientific research. This project consisted of two implementations of an experiential learning module at two universities. These modules were embedded in existing courses and included activities such as conducting interviews with scientists and developing science communication messaging. Students completed written reflections, science writing samples, and science attitudes and beliefs questionnaires as a part of the project. Although results showed no changes in students' writing ability, there were increases in their science literacy self-efficacy and deference to scientific authority. Additionally, reflections showed that students were learning about the scientific process. These findings suggest that this module is a viable learning activity that can be incorporated into existing courses to expose students to scientific research and build communication skills. For future implementations of similar projects, it is recommended that the project contained in this module be the major project of the course as opposed to one of several projects in the course.

Keywords: Science, communication, experiential learning, writing quality, science beliefs

Government agencies and universities depend on public support, even from segments of the population who are not directly affected by those organizations (Hoggett, 2006; Moore, 1995). These organizations risk losing funding, especially in a fiscal environment that has seen spending cuts at local and national levels. Research has shown that several factors are expected to influence public support for science funding, including science knowledge, "interest in science," beliefs about the risks and benefits of science, and trust or "confidence in scientific institutions" (Besley, 2018, p. 97).

Existing surveys provide insight into the presence and levels of these predictors of support for science in the U.S., and the findings show room for improvement (National Academies of Sciences, Engineering, and Medicine, 2016; National Science Board, 2018). The general public shows relatively stable science knowledge and interest over the past two decades (National Science Board, 2018); respondents to a 2016 national survey correctly answered an average of 5.6 out of 9 knowledge items, and approximately "4 out of 10 Americans say they are 'very interested' in new scientific discoveries" (National Science Board, 2018, p. 3). Scientists are generally trusted the most among different sources of scientific information, but there is still a large segment of the population that does not trust the scientific community (Funk, 2017). In fact, the National Science Board (2018) estimates that only about 40% of the public has a great deal of trust in the science community. Science communication may offer an opportunity to increase knowledge, science interest, trust in scientific institutions, and positive beliefs about science, as suggested by the goals of science communication identified by the National Academies of Sciences, Engineering, and Medicine, (2016), but "communicating science effectively… is a complex task and an acquired skill" (p. 1).

This study included assessment of interest in science-related careers, deference to scientific authority, and science literacy self-efficacy. Interventions have shown the ability to increase interest in science-based careers (Binns et al., 2016; Chen & Chang, 2018). Krumboltz and Worthington (1999) recommended expanding students' career interest areas, as opposed to only trying to match careers to their current interests. Rozenzweig and Chen (2023) found that students' interest in STEM careers can vary based on student demographics. Deference to scientific authority is important because it can affect adoption, such as being a strong predictor of support for biotechnology (Brossard & Nisbet, 2006). Osborne and Allchin (2024) conceptualized scientific literacy as consisting of an understanding of the norms of a community of scientists, being able to assess credibility of those communicating about science, understanding what major areas of scientific consensus exist, and understanding the scientific reasoning that underpins research. Self-efficacy in this realm would then address the students' belief in their science literacy, which helps predict their behavior through their willingness to keep trying to grow and learn (Bandura, 2006). Self-efficacy and career interest are correlated, indicating improving one may improve the other (Settle et al., 2012).

Although interest in teaching science communication continues to grow (e.g., Fähnrich et al., 2021; Mellor, 2013; Trench, 2012), a lack of research means teaching practices are not always evidence based. Science communication as an academic discipline is still relatively new and lacks consistency as a result (i.e., there are a wide variety of approaches being explored; Mellor, 2013; Trench, 2012). Although there is a small and growing body of empirical research on how to teach science communication (e.g., Ritchie et al., 2011), there is still a need to set benchmarks for effective science communication tactics and evaluate the efficacy of training programs (Baram-Tsabari & Lewenstein, 2017). Within the realm of science communication education, writing is an area of particular importance, and Rockers and Rumble (2023) indicated there was a need for teachers to have students focus on the writing process more. Another area to improve science knowledge is the role of research in social sciences, including communication. Masambuka-Kanchewa and Lamm (2022) found that students in their study who were studying agricultural leadership, education, and communication did not perceive themselves as scientists at the beginning of their course but came to see that they could be scientists. Masambuka-Kanchewa and Lamm stated there was a gap in undergraduate curricula for showing students a broader view of science careers.

This project included the development and implementation of a novel experiential-learning science communication module that can be incorporated into existing or new communication courses. Using experiential learning as a framework, students produced science communication materials, and the materials were then tested with public audiences. This was to help students develop science literacy and understand the research that underpins science communication as they improved their science communication skills. The goal of the research was to advance knowledge about the application of experiential learning and best practices for teaching science communication while also contributing to the literature on science communication by having students research a question of importance to the field.

Experiential Learning

Over recent years, calls have been made to implement high-impact educational practices to increase student engagement and success (Kuh, 2008). Many of these practices, such as research, community-based learning, and capstone projects, are forms of experiential learning, which treats learning as a process grounded by a practical experience (Rock, 2025). Experiential learning is recommended by Washburn et al. (2022) to improve science communication.

A variety of theorists created the foundation that would become experiential learning, including Piaget, Dewey, Lewin, and Jung (Kolb & Kolb, 2005). Kolb and Kolb (2005) summarized six commonalities from these theorists in the development of experiential learning:

> 1. Learning is best conceived as a process, not in terms of outcomes. … 2. All learning is relearning. … 3. Learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world. … 4. Learning is a holistic process of adaptation to the world. … 5. Learning results from synergistic transactions between the person and the environment. … 6. Learning is the process of creating knowledge. (p. 194)

While there are many cited uses of experiential learning across a variety of settings, such as plant science (Bauerle & Park, 2012), medicine (Silenas et al., 2008), and business (Lefebvre & Redien-Collot, 2013), it is common for teachers to conflate class activities as being experiential learning: "Simply providing experiences does not constitute learning" (Baker et al., 2012, p. 12). Activities are a part of the process, but the full cycle of experiential learning needs to be addressed to help ensure learning occurs as effectively as possible.

One way to improve the use of experiential learning in education is through the application of Kolb's experiential learning cycle (Kolb & Kolb, 2012), which proposes four stages: concrete experience (e.g., engaging in an experience), reflective observation (e.g., thinking about the experience), abstract conceptualization (e.g., making generalizations from the experience), and active experimentation (e.g., test generalizations gained from the experience elsewhere in the world). Learners can enter the cycle at any point, but they keep looping through the cycle once they are engaged in the learning process. Before engaging in a class activity (i.e., concrete experience), students walk in with past experiences in the world (i.e., active experimentation), which affects their interpretation of the experience (i.e., reflective observation) and how they make generalizations after that (i.e., abstract conceptualization). This, in turn, starts the loop over again by affecting how students engage in the world around them.

The current research project had students engaged in research about science communication, with active integration of Kolb's experiential learning cycle included in the design of the assignment module. In addition to learning about science communication, the students were also engaging in research about that topic, which has received much attention in recent years (Fischhoff & Scheufele, 2013, 2014; Jamieson et al., 2017; National Academies of Sciences, Engineering, & Medicine, 2016). Students' role in the research process was to develop materials to test if the medium of communication (e.g., text only, audio only, or video only) affected evaluations of the narrative being communicated to lay audiences by humanizing scientists, an area of research inspired by Schroeder et al. (2017).

Assignment Module

The assignment module was tested at two universities: Oklahoma State University (OSU) and Mississippi State University (MSU). The OSU course for the project was an issues, risk, and crisis communication in agriculture and natural resources course. At MSU, the project was implemented in an introductory communication course and served as the small group communication project (replacing the typical small group assignments, which typically included multiple discussion posts about group communication concepts and a reflection).

At OSU, the module consisted of pre-implementation assessments (i.e., a questionnaire and science writing sample), an eight-week experiential learning module, and post-implementation assessments (i.e., a questionnaire and a second science writing sample). In the experiential learning module, students developed science communication materials (i.e., concrete experience) that were then tested for effectiveness using an online survey-based experiment. Students completed written reflections each week on module activities (i.e., reflective observation).

Teams of students who were in the same class were paired with a scientist at their respective universities to decide on a domain of scientific information to be communicated. Using the process for developing prescriptive scientific narratives outlined by Downs (2014), students conducted a domain-specific assessment, which included the development of an "expert model" (i.e., what the public needs to know) and a "descriptive model" (i.e., what the public understands about the topic). The students then conducted a video-recorded interview with the scientist and developed a narrative message that included the key components of a prescriptive scientific narrative identified by Downs (2014): "narrator's voice," "conflict within context," and "action and resolution" (p. 13628). Student teams created three versions of the narrative message to be tested: one video, one audio only (the exact audio from the video piece), and one text transcript of the audio. The three versions of each message were tested with adults in an online sample of U.S. adults. At OSU, the students analyzed the data and drew conclusions about the effectiveness of the various messages (i.e., abstract conceptualization). The results of message testing with the public audience are being reported in a separate research paper. The activity was designed with the intent that, after the conclusion of the project, the students would then be able to apply what they learned from the experiments in future communication activities (i.e., active experimentation), though that goes beyond the scope of what can be assessed in this study.

In the second implementation at MSU, students also completed the pre-implementation assessments (a questionnaire and science writing sample), the eight-week experiential learning module (detailed previously), and post-implementation assessments (a questionnaire and a second science writing sample). However, the experiential learning module was simplified and shortened to be more easily incorporated into the course and be more appropriate for an introductory course based on the feedback from the first implementation. Students met in groups to develop a group contract and interview guide, interviewed their assigned scientist, completed a written reflection on their interview, worked to produce and submit the video with accompanying audio and text files, and completed a written reflection on the entire module. Thus, this implementation removed the testing and analysis component, which lessened the overall time students at MSU spent on the project.

The students completed the following preflection and reflections. At OSU, students completed a reflection on IRB training, a preflection on interviews, a reflection on the interview, and a reflection on the analysis and interpretation process. At MSU, the reflections were adjusted to be appropriate for the adjusted process: the students completed a reflection on the interview and a reflection on the entire module.

Purpose & Objectives

The purpose of this study was to determine the effects of a science communication experiential learning module. The objectives of this study were to

1. Determine the effects on students' science writing quality,
2. Determine the effects on students' perceptions related to science, and
3. Determine students' perspectives on the module through reflections.

Methods

The study used a convergent mixed methods design (Creswell & Plano, 2018) that involved collection of quantitative and qualitative data (with a larger emphasis on quantitative data) to investigate complementary research objectives. The primary change the project sought to address is if the experiential learning module improved undergraduate students' science communication competence as measured through analysis of writing samples. Secondary outcomes included increasing interest in science-related careers (including careers in science communication), deference to scientific authority, and science literacy self-efficacy. These outcomes were measured through pre- and post-implementation questionnaires. Finally, we used thematic analysis of written reflections to assess student perspectives on the module and metacognitive insights.

The population for this study consisted of students in communication classes at two universities. At OSU, the class was risk and crisis communications in agriculture and natural resources and were all juniors and seniors. One student was a natural science student, but the remainder were in agricultural communications. Of the 33 students, 12 agreed to participate. At MSU, the class was a general communication course with 33 students from majors across the university, of which 29 agreed to participate. The majority of MSU students were freshmen and sophomores, though there were also juniors and seniors included. Institutional Review Board approval was obtained at both universities (OSU IRB-20-159 & MSU IRB-18-295). Students were required to engage in all aspects of the project for the course but were then asked after the project was completed if they consented to having their responses included in research.

For the writing samples, students were asked to write an explanation of a scientific concept – why antibiotics are not prescribed for flu in the pre-test and how police identify people based on DNA for the post-test – as if they were explaining to family members in 75 to 150 words. These were then evaluated based on a rubric adapted from Rakedzeon and Baram-Tsabari (2017) that assessed active voice, readability, explanation, wordiness, definitions use, and example use. Active voice and readability were calculated using Microsoft Word's readability statistics. The same two coders evaluated the writing samples for both implementations for the remaining variables. First they met to ensure they were in agreement about how to evaluate the writing samples. After they were in agreement, they evaluated the remainder of the prompts individually, though each coder evaluated each sample. For items where they were not in agreement, the first author on this paper evaluated the item to determine the final coding. Means were run on the constructs (e.g., active voice and readability), which were compared using paired-samples t-tests.

Students also completed pre- and post-course questionnaires about science literacy self-efficacy, deference to scientific authority, and interest in science careers. Science literacy self-efficacy was measured using five items from a scale validated by McKeown (2017; attributed to Fives et al., 2014). Statements were evaluated on a 1 = *strongly disagree* to 5 = *strongly agree* scale, and the scale included the following items: "I know when to use science to answer questions," "I can use science to make decisions about my daily life," "I know how to use the scientific method to solve problems," "It is easy for me to tell the difference between scientific findings and advertisements," and "I can tell the difference between observations and conclusions in a story." These items had a Cronbach's alpha of .81 in the pretest and .91 for the posttest and were averaged to create a measure of science literacy self-efficacy. Deference to scientific authority was measured using three items from Brossard and Nisbet (2006): "Scientists know best what is good for the public," "It is important for scientists to get research done even if they displease people by doing it," and "Scientists should do what they think is best, even if they displease people by doing it." These items were evaluated on a 1 = *strongly disagree* to 4 = *strongly agree* scale. The scale had a Cronbach's alpha of .77 in the pretest and .86 in the posttest, and items were averaged to create a measure of deference to scientific authority. Interest in science careers was measured using items 1 through 4 and 6 through 12 from the Career Interest Questionnaire (Christensen et al., 2014). The fifth item was removed because it was about selecting a college and major, which was not relevant to the participants of this study. This scale included items such as "I would enjoy a career in science" and "I will graduate with a college degree in a major area needed for a career in science" that were evaluated on a 1 = *strongly disagree* to 5 = *strongly agree* scale. These items had a Cronbach's alpha of .95 in the pretest and .93 in the posttest and were averaged to create a measure of interest in science careers. Pre- and post-course data were analyzed via paired samples t-tests in SPSS.

As a part of the assignment, students completed reflections throughout the process. For the implementation at OSU, they completed the following reflections:

1) Reflections on IRB trainings – Write a paragraph or two (approximately 200-300 words) in which you answer the following questions: What did you learn from the process of completing IRB training? Specifically, please focus on what you learned about research and ethics.

2) Preflections before their interviews – "Preflect" is a term used to describe the act of looking ahead and thinking about something we may experience. You will write a paragraph or two (200-300 words) in which you answer the following questions: What do you expect and/or hope to learn from this interview with the scientist? What have you done to prepare for this experience? What challenges do you expect in putting together a cohesive message to test?

3) Reflections on their interviews – Write a paragraph or two (200-300 words) in which you answer the following questions: What did you learn from the interview? Was there anything unexpected you learned from the interview?

4) Reflections on the analysis and interpretation process – Write a paragraph or two (200-300 words) in which you answer the following questions: What did you learn about research from this process? What are your thoughts about the results of the research?

For feasibility based on the OSU implementation, the number of reflections was reduced at MSU and included a reflection on the interview and a reflection on the entire module using the following prompts:

1) Reflections on their interviews - Reflect on the interview your group conducted with a scientist. Write a paragraph or two (approximately 250 words) in which you answer the following questions: What did you learn about communication from the interview? What most surprised you? What communication challenges did you face?

2) Reflections on the completed project - Reflect on the entire group project. Write a paragraph or two (approximately 250 words) in which you answer the following questions: What did you learn about science communication? What did you learn about small group communication? How might you use what you learned in your future life or career?

This qualitative data was analyzed for themes using the Braun and Clark (2006) method, which occurs in six phases: "1. Familiarizing yourself with the data" (i.e., reading the data and taking notes), "2. Generating initial codes" (i.e., systematic coding of interesting initial features of the data), "3. Searching for themes" (i.e., gathering codes into relevant themes), "4. Reviewing themes" (i.e., verifying if themes work in relation to each other and the data), "5. Defining and naming themes" (i.e., determining a name that tells the story of the theme), and "6. Producing the report" (i.e., selection of illustrative quotes for this research paper; p. 87).

Results

Objective 1: Students' Science Writing Quality

Students' science writing samples did not show evidence of increases in science communication competence when evaluated using a rubric adapted from Rakedzon and Baram-Tsabari (2017) that assessed active voice, readability, explanation, wordiness, definitions use, and example use. There was not a statistically significant difference in the quality of science writing samples produced at the end of the course compared to those produced at the beginning of the course (Table 1).

Objective 2: Students' Perceptions Related to Science

There was evidence of some student outcomes that would not typically be expected in a communication courses not focused on science communication and may be the result of the experiential science communication module (Table 2). For example, comparison of pre- and post-implementation assessment questionnaires indicated statistically significant positive changes in science literacy self-efficacy (t = -2.30, p = .03) and deference to scientific authority (t = -2.76, p < .01). There were not statistically significant changes in interest in science careers.

Objective 3: Students' Perspectives on the Module

The first theme from the reflections was personal attributes, where participants indicated how their own preparation, personal connections, and personal expectations affected their experiences. A student at OSU said, "Overall, I think my big takeaway is that research is daunting but rewarding. It can be a bit of a challenge to organize and interpret, but the results are valuable and beneficial, as new knowledge is learned." A student at MSU said, "One of the biggest things I learned in science communication is that it's important to have at least a small understanding of the topic in discussion in order to fully grasp what the scientist is teaching. It is difficult to keep up and to gain knowledge on a concept if you have no prior knowledge."

Table 1

Science writing scores (N = 29)

	Pre		Post	
	M	*SD*	*M*	*SD*
Active voice[a]	75.93	22.40	75.55	18.19
Grade level[a]	9.81	2.70	9.63	1.97
Readability[b]	59.07	11.96	59.75	11.93
Overall explanation[b]	2.59	0.91	2.59	0.78
Wordiness[c]	2.69	0.60	2.59	0.63
Appropriate word use[d]	2.52	0.51	2.55	0.57
Example application[e]	2.90	0.72	3.03	0.33

[a]*Calculated in Microsoft Word*

[b]*1 = completely incoherent; complete lack of logic/explanation; 2 = mostly incoherent explanation; major logical gaps; 3 = Mostly coherent explanation; may have some logical gaps; and 4 = fully coherent, logical explanation*

[c]*1 = includes a great deal of wordiness, 2 = used some concise language (some wordiness), 3 = uses mostly concise language (almost no wordiness), and 4 = uses concise language (no wordiness)*

[d]*1 = Incomprehensible; inappropriate use of terminology; complete lack of definitions; 2 = full of technical terms inappropriate for audience; 3 = minimal use of jargon; some definitions given; and 4 = No jargon, language appropriate for nontechnical audience; defines technical terms*

[e]*1 = No example included, 2 = Used example that was not applicable, 3 = include vague but appropriate example, and 4 = included appropriate example*

Table 2

Science attitudes and beliefs (N = 35)

	Pre		Post	
	M	*SD*	*M*	*SD*
Science literacy self-efficacy[a*]	3.57	0.74	3.91	0.86
Interest in science careers[a]	3.28	1.01	3.48	1.05
Deference to scientific authority[b*]	3.04	0.78	3.49	0.88

[a] *1 = strongly disagree, 5 = strongly agree*
[b] *1 = strongly disagree, 4 = strongly agree*
* *p < .05*

The second theme was challenges, which stemmed from dysfunctions in project teams, technology issues, and challenges with learning something new, as most of them had not engaged in the types of activities involved in this activity. A student at MSU said,

Actually, it was very hard to get my group to begin communicating in the first place. During our first meeting, I believe it was only myself and [group member] talking, but eventually we were able to get some of our other group members to chime in from time to time. I believe the group would have run a bit more smoothly if we had communicated a bit better. I learned that sometimes group work gets distributed unevenly when others fail to communicate and become a working member of the group.

The third theme was what students learned, which included information that would be potentially helpful in the future and understanding research concepts. A student at MSU said, “I will use what I’ve learned in my career by trying to make sure that I keep information concise when it is necessary. Especially because I want to be an emergency veterinarian, it will be important to make sure I get to the point as quickly as possible in a lot of situations and not get distracted and digress from the issue at hand.” A student at OSU said, “The research we did helped me to realize that research is just as much a part of communications as it is to a stereotypical science career. That was neat to learn because I often associate research with lab science, like chemistry or biology; however, it relates to my field a great deal, and the results proved to me just how important my career choice is.”

Summary of Results

Taken together, the experiential learning module impacted perceptions related to science, including science literacy self-efficacy and deference to scientific authority. The qualitative findings helped provide contextualization, particularly for understanding the connections between research and communication, as well as applying these concepts to future careers. While these impacts were documented, there were also areas of improvement for the project, specifically teamwork and technology issues.

Discussion

While writing is a particularly important area of communication that needs improvement (Rockers & Rumble, 2023), the project did not have a statistically significant impact on their science writing ability. Because this was not an experimental design, a specific cause cannot be determined for the lack of effect, but it is possible a project with more writing would be more efficacious. As such, those seeking to improve writing quality may want to try more direct interventions (e.g., writing labs and tutoring programs), as opposed to a general module on science communication.

There was an increased deference to scientific authority and, consistent with past literature (Funk, 2017), the students had fairly positive perceptions toward the scientists. The students had an increase in believing in their own knowledge of when to use science, demonstrated through significant increases in scores on the science literacy self-efficacy scale. They also had an increased interest in science careers, though not at a statistically significant level. Given the need for public support of science funding and the importance of science attitudes for that support, projects that can improve perceptions of research and researchers may influence research support in the future (Besley, 2018).

Similar to past research by Masambuka-Kanchewa and Lamm (2022), reflections showed an increased awareness of the role research plays in science communication. This is important as students explore careers related to science, including the science of science communication. The reflections are a particularly important area to address. Reflection is a critical component of the experiential learning cycle (Kolb & Kolb, 2012) that helps students learn, but formal reflections can be a valuable component for instructors seeking to improve the learning process. The project also challenged students to learn something new, and the reflections show there were difficulties at times, but the results of the project, including reflections, illustrate areas of growth. This is consistent with prior research demonstrating that more active learning methods produce greater learning, but the increased cognitive effort necessary for active learning can lead to lower levels of enjoyment and lower perceived learning (Deslauriers et al., 2019). As the teaching of science communication increases, efforts to formalize the evaluation process will continue to be needed to ensure students are taught as effectively and efficiently as possible (Mellor, 2013; Trench, 2012), and instructors should incorporate strategies from Deslauriers et al. (2019) to help students understand the value of active learning, such as research project, case studies, and debates.

One of the lessons learned was that if the project is implemented in a course and having student engage in analysis, it should be the major project of the class instead of a major project in the class. The initial implementation at OSU was overwhelming at times for students because the project was more involved than the assignment it replaced for the class. When the module was simplified for the MSU implementation, it was more manageable as part of a course that required other units and major assignments.

This activity and its assessments had both strengths and limitations. The primary limitation of this activity and the associated assessment was that it occurred during the COVID-19 pandemic. The OSU implementation took place in the spring of 2020. While the recording of interviews occurred before students were sent home for the semester, the analysis portion occurred during the initial foray into distance learning. The MSU implementation was in the fall of 2020, and the course was taught synchronously online as a result. All groupwork and scientist interviews took place via videoconference. The change in the assignment module of not having students analyze collected results may also mean there were differences between implementations, though we did not compare implementations due to the limited sample size at each individual site. A second limitation is that the activity and our findings may not translate to all university settings and student populations. However, the successful implementation of this activity in two different departments, courses, and student populations demonstrates its potential to have an impact on student outcomes related to science literacy and science communication. Another limitation is not being able to assess impacts past the class. Long-term research is needed to understand impacts of similar types of projects.

Summary

In conclusion, this research examined the effect of an experiential science communication activity through the use of science writing samples, questionnaires, and written reflections. Results demonstrated increases in students' deference to scientific authority and science literacy self-efficacy, though there were not improvements in the students' science writing quality. The project demonstrates the feasibility of incorporating this activity into existing courses and provides evidence for engaging students in science communication practice and research. Without engaging in an experimental design, it is difficult to say how the outcomes of the approach differ from other models of teaching, but the qualitative results indicated students grew in their appreciation for the research process and how it applies to communication. Consequently, this type of activity may contribute not only to improving communication skills but also to increasing public support for science.

References

Baker, M. A., Robinson, J. S., Kolb, D. A. (2012). Aligning Kolb's experiential learning theory with a comprehensive agricultural education model. *Journal of Agricultural Education, 53*(4), 1-16. https://doi.org/10.5032/jae.2012.04001

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajeres & T. Urdan (Eds.) *Self-efficacy beliefs of adolescents* (pp. 307-337). Information Age Publishing.

Baram-Tsabari, A., & Lewenstien, B. V. (2017). Science communication training: What are we trying to teach? *International Journal of Science Education, Part B, 7*(3), 285-300. https://doi.org/10.1080/21548455.2017.1303756

Bauerle, T. L., & Park, T. D. (2012). Experiential learning enhances student knowledge retention in the plant sciences. *Teaching Methods, 22*(5), 715-718. https://doi.org/10.21273/HORTTECH.22.5.715

Besley, J. C. (2018). The National Science Foundation's science and technology survey and support for science funding, 2006-2014. *Public Understanding of Science, 27*(1), 94-109. https://doi.org/10.1177/0963662516649803

Binns, I. C., Polly, D., Conrad, J., & Algozzine, B. (2016). Student perceptions of a summer ventures in science and mathematics camp experience. *School Science and Mathematics, 116*(8), 420-429. https://doi.org/10.1111/ssm.12196

Braun, V., & Clark, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Brossard, D., & Nisbet, M. C. (2006). Deference to scientific authority among a low information public: Understanding U.S. opinion on agricultural biotechnology. *International Journal of Public Opinion Research, 19*(1), 24–52. https://doi.org/10.1093/ijpor/edl003

Chen, Y., & Chaung, C. (2018). The impact of an integrated robotics STEM course with a sailboat topic on high school students' perceptions of integrative STEM, interest, and career orientation. *Eurasia Journal of Mathematics, Science, and Technology Education, 14*(12). https://doi.org/10.29333/ejmste/94314

Christensen, R., Knezek, G., & Tyler-Wood, T. (2014). *Career Interest Questionnaire (CIQ)* [Database record]. APA PsycTests. https://doi.org/10.1037/t33611-000

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). Sage.

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. *Proceedings of the National Academy of Sciences, 116*(39), 19251–19257. https://doi.org/10.1073/pnas.1821936116

Downs, J. S. (2014). Prescriptive scientific narratives for communicating usable science. *Proceedings of the National Academy of Sciences, 111*, 13627–13633. https://doi.org/10.1073/pnas.1317502111

Fähnrich, B., Wilkinson, C., Weitkamp, E., Heintz, L., Ridgway, A., & Milani, E. (2021). RETHINKING science communication education and training: Towards a competence model of science communication. *Frontiers in Communication, 6*. https://doi.org/10.3389/fcomm.2021.795198

Fischhoff, B., & Scheufele, D. A. (2013). The science of science communication. *Proceedings of the National Academy of Sciences, 110*(Supplement 3), 14031–14032. https://doi.org/10.1073/pnas.1312080110

Fischhoff, B., & Scheufele, D. A. (2014). The Science of Science Communication II. *Proceedings of the National Academy of Sciences, 111*(Supplement 4), 13583–13584. https://doi.org/10.1073/pnas.1414635111

Fives, H., Huebner, W., Birnbaum, A. S., & Nicolich, M. (2014). Developing a measure of scientific literacy for middle school students: Developing a measure of scientific literacy. *Science Education, 98*(4), 549–580. https://doi.org/10.1002/sce.21115

Funk, C. (2017). *Mixed messages about public trust in science.* Pew Research Center. Retrieved from http://www.pewinternet.org/2017/12/08/mixed-messages-about-public-trust-in-science/

Hoggett, P. (2006). Conflict, ambivalence, and the contested purpose of public organizations. Human Relations, 59(2), 175-194. https://doi.org/10.1177/0018726706062731

Jamieson, K. H., Kahan, D. M., & Scheufele, D. (Eds.). (2017). *The Oxford handbook on the science of science communication.* New York, NY: Oxford University Press.

Kolb, A. Y., & Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning & Education, 4*(2), 192-212.

Kolb, A. Y., & Kolb, D. A. (2012). Experiential learning theory. In N. M. Seel (Ed.) *Encyclopedia of the Sciences of Learning.* https://doi.org/10.1007/978-1-4419-1428-6_227

Krumboltz, J.D., & Worthington, R.L. (1999). The school-to-work transition from a learning theory perspective. *The Career Development Quarterly, 47*, 312-325. https://doi.org/10.1002/j.2161-0045.1999.tb00740.x

Kuh, G. (2008). *High-impact educational practices: what are they, who has access to them, and why they matter.* Association of American Colleges and Universities. https://www.aacu.org/publication/high-impact-educational-practices-what-they-are-who-has-access-to-them-and-why-they-matter

Lefebvre, M. R., & Redien-Collot, R. (2013). "How to do things with words": The discursive dimension of experiential learning in entrepreneurial mentoring dyads. *Journal of Small Business Management, 51*(3), 370-393. https://doi.org/10.1111/jsbm.12022

Masambuka-kanchewa, F. (2023). Perceptions of Scientists before and after Taking a Graduate Level Science Communication Course: Graduate Students' Perceptions of a Scientist . *North American Colleges and Teachers of Agriculture Journal, 66*(1), 113-121. Retrieved from https://nactajournal.org/index.php/nactaj/article/view/30

Matheson, S. (2017). Going public in support of science. *Cell, 169,* 181–182. http://dx.doi.org/10.1016/j.cell.2017.03.029

McKeown, T. (2017). *Validation study of the Science Literary Assessment: A measure to assess middle school students' attitudes toward science and ability to think scientifically* [Doctoral dissertation, Virginia Commonwealth University]. VCU Scholars Compass. https://scholarscompass.vcu.edu/etd/5080/

Mellor, F. (2013). Twenty years of teaching science communication: A case study of Imperial College's Master's programme. *Public Understanding of Science, 22*(8), 916-926. https://doi.org/10.1177/0963662513489386

Moore, M. H. (1995). Creating public value: Strategic management in government. Cambridge, MA: Harvard University Press.

National Academies of Sciences, Engineering, and Medicine. (2016). *Communicating Science Effectively: A Research Agenda.* Washington, DC: The National Academies Press. https://doi.org/10.17226/23674

National Science Board. (2018). Chapter 7: Science Technology : Public Attitudes and Understanding. In *Science and Engineering Indicators 2018*. NSB-2018-1. Alexandria, VA: National Science Foundation. https://www.nsf.gov/statistics/2018/nsb20181/assets/404/science-and-technology-public-attitudes-and-understanding.pdf

Osborne, J., & Allchin, D. (2024). Science literacy in the twenty-first century: Informed trust and the competent outsider. *International Journal of Science Education,* 1–22. https://doi.org/10.1080/09500693.2024.2331980

Rakedzon, T., & Baram-Tsabari (2017). To make a long story short: A rubric for assessing graduate students' academic and popular science writing skills. *Assessing Writing, 32,* 28-42. https://doi.org/10.1016/j.asw.2016.12.004

Ritchie, S., Tomas, L., & Tones, M. (2011). Writing stories to enhance scientific literacy. *International Journal of Science Education, 33,* 685–707. https://doi.org/10.1080/09500691003728039

Rock, A. E. (2025). Community-based learning as experiential learning in geography. In J. E. Wessell (Ed.), *Experiential learning in geography: The world as our classroom* (pp. 61-72). Springer. https://doi.org/10.1007/978-3-031-82575-0_4

Rockers, A., & Rumble, J. N. (2023). Agricultural communication students' media writing self-perception in an writing self-perception in an introductory course. *North American Colleges and Teachers of Agriculture Journal, 67*(1), 211-217. https://doi.org/10.56103/nactaj.v67i1.62

Rosenzweig, E. Q., & Chen, X. (2023). Which STEM careers are most appealing? Examining high school students' preferences and motivational beliefs for different STEM career choices. *International Journal of STEM Education, 10.* https://doi.org/10.1186/s40594-023-00427-6

Schroeder, J., Kardas, M., & Epley, N. (2017). The humanizing voice: Speech reveals, and text conceals, a more thoughtful mind in the midst of disagreement. *Psychological Science, 28*, 1745-1762.

Settle, Q., Doerfert, D. L., Irlbeck, E., Akers, C., Burris, S., Wingenbach, G., & Rutherford, T. (2012). The effects of an agricultural communications workshop on self-efficacy and career interest: A comparison between agriculture and non-agriculture students. *North American Colleges and Teachers of Agriculture Journal, 56*(4), 71-77.

Silenas, R., Akins, R., Parrish, A. R., & Edwards, J. C. (2008). Developing disaster preparedness competence: An experiential learning exercise for multiprofessional education. *Teaching and Learning in Medicine, 20*(1), 62-68. https://doi.org/10.1080/10401330701798311

Smith, T. W., Davern, M., Freese, J., & Hout, M. (2017). *General Social Surveys, 1972-2016: cumulative codebook.* Chicago, IL: NORC. Retrieved from http://gss.norc.org/documents/codebook/GSS_Codebook.pdf

Trench, B. (2012). Vital and vulnerable: Science communication as a university subject. In B. Schiele, M. Claessens, & S. Shi (Eds.) *Science Communication in the World*. Springer, Dordrecht, Netherlands.

Washburn, T., Essary, C., Irlbeck, E., Gibson, C., & Akers, C. (2022). Foreseen demands for up-and-coming science communicators and recommendations for science communication training programs. *Journal of Applied Communications, 106*(2). https://doi.org/10.4148/1051-0834.2410