TIPS, TRICKS & TECHNIQUES

Sabotaging Presentations to Generate Fundamental Questions and Integrate Theory and Practice

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ABSTRACT

Many teachers who assign scientific research projects to students require them to present their research to their classmates. Although it is important for science students to develop research presentation skills, it is questionable whether class presentations are an effective learning tool for audience members. In this article, we describe a dynamic and interactive presentation exercise that can be used for either formative or summative assessment, which challenges students to share their expertise with their peers via a unique motivating structure. Students practice their presentation skills while engaging authentically in a process of developing crosscutting, interdisciplinary fundamental scientific questions that integrate scientific theory and practice. This exercise may be useful in science courses in which students are expected to critically and creatively engage in and reflect upon scientific processes and content.

Key Words: *application of theory; framing theories; fundamental questions; integration; presentations; project-based learning; theory and practice.*

○ Introduction

The Limitations of Presentations

Commonly in high school and college science courses, students are required to give presentations about short- and long-term research projects. It is important for science students to develop research presentation skills because the scientific community uses presentations to exchange ideas and information, and because students may later play important roles in communicating science to colleagues, policymakers, and the public (AAAS, 2011; NRC, 2012). However, regardless of the presentation medium (e.g., digital presentation, enactment, demonstration), the presenter may benefit more than the audience. The exercise we describe here changes that dynamic by motivating audience members to collaboratively accomplish an intriguing task using the content of each other's presentations. Along the way students analyze and synthesize scientific theories, craft fundamental scientific questions, and reflect upon their presentation skills.

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PowerPoint is the world's most popular medium for presenting information (Tufte, 2003; Mahin, 2004), and its use for research presentations in biology classrooms and at STEM conferences is ubiquitous. Nonetheless, PowerPoint has drawn criticism from those who claim that its use may compromise the depth with which users engage with complex content, and for its limitations in facilitating the presentation of coherent ideas and information (Keller, 2003; Tufte, 2003; Frommer, 2012). Perhaps more importantly, ineffective presentations can be stultifying for audiences (Gibbons, 2003; Goldstein, 2003; Keller, 2003; Baranowski & Wier, 2011). Although strategies like scaffolding presentation assignments (Bayless, 2004; Mahin, 2004) and the use of storyboards (Bayless, 2004; Vik, 2004) can help improve the quality of presentations, they still may not sufficiently engage listeners and optimize opportunities for student learning. Thus, biology teachers may wish to consider alternative ways to structure class presentations that enhance student engagement with content and information exchange.

Generating Fundamental Scientific Questions

An important aspect of science is its predictive power (Weiner, 1995; Pickett et al., 2007). To advance scientific theory and improve its predictive power, scientists must ground their applied research in fundamental questions (Pickett et al., 2007; Sutherland et al. 2013) that "lead to the establishment, refinement, rejection, replacement, or expansion in the scope of a theory or its components" (Pickett et al., 2007, p. 130). Sutherland and colleagues (2013) define fundamental

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questions as those that advance our understanding of a particular scientific discipline, whether or not the answers address problems facing humanity or society. In this era of rapid climate change and biodiversity loss, the capacity of scientists to predict local, regional, and global scientific processes is increasingly critical (Courchamp et al., 2014), and rigorous training of effective scientists and science communicators is more important than ever (AAAS, 2011; NRC, 2012). Thus, science teachers must craft lessons that enhance students' abilities to use theory and research to formulate fundamental questions that integrate scientific disciplines (Pickett et al., 2007; Sutherland et al., 2013; Courchamp et al., 2014; Westmoreland, 2015). Emphasizing the feedbacks between theory and practice trains students to ground their questions about the natural world in the history of scientific inquiry, thereby increasing the relevance of their own scientific research.

The exercise described here may be used in various science courses in which students are expected to critically and creatively engage in and reflect upon the scientific process, and in which they are expected to present their projects to peers. We have used the exercise in an interdisciplinary, graduate-level ecology course with students who had minimal prior ecology training. In this course, students design and conduct a semester-long ecology research project of their choice, which includes a proposal stage during which the teacher provides feedback and guides students toward the bodies of theory pertinent to their chosen research topics. Student projects have included the effects of temperature and humidity on pill bug locomotion, whether native and invasive anoles show spatial partitioning in tropical trees, and whether deer congregate on suburban lawns during hunting season. Through the exercise, students give science presentations to small groups, practice self-assessment, and consider feedback from peers. Just as importantly, listeners are actively engaged in working with the material being presented, specifically theory and fundamental question generation.

Teachers can use this exercise in high school, undergraduate, or graduate science courses to achieve the following student learning outcomes:

1. Demonstrate clear and precise communication about scientific course content and project planning and execution.
2. Apply scientific inquiry, using current and relevant theory, applied questions, and valid scientific methods.
3. Demonstrate understanding of the role of theory in formulating questions about the natural world, and apply theory to research question generation and interpretation of results.
4. Demonstrate capacity for authentic self-assessment.
5. Demonstrate capacity to provide honest and constructive feedback to peers.
6. Demonstrate understanding of seminal scientific theory and integration of theory and application.
7. Collaborate with peers to integrate theories into new and unifying fundamental questions.

These learning outcomes can readily be used as criteria in a learning rubric designed to help students understand the teacher's expectations.

○ Exercise Description in Rounds

Round 1: Integrating Research into Unifying Fundamental Questions

To begin the exercise, the instructor selects small groups of 3–4 students to maximize the diversity of research projects per group. Students will need to meet in small groups without hearing the other groups, so everyone in each group can share their respective presentations. Before students present their research to one another, it is important to define what is meant by "fundamental questions" in science and to discuss examples (Pickett et al., 2007; see Sutherland et al., 2013, for examples). In this round, students spend two hours with their small groups, during which each student presents their research to their group and answers any questions; typically each student has 15 minutes to present and then answer questions. (The teacher may vary the time depending upon grade level, group size, and time constraints; alternatively, the teacher may spread this exercise over more than one class period.) During the presentation, each listener notes strengths and weaknesses of the presentation. In addition, each listener writes down the primary scientific theory the presenter uses to frame their research project (Table 1). After the presenter finishes their presentation, the presenter and listeners briefly (≤5 minutes) confer about the strengths of the presentation and identify ways it can be improved.

After the brief critique period, the listeners try to guess the primary scientific theory framing the presenter's project, while the presenter listens and provides feedback to the listeners. To ensure that listeners remain engaged with each presentation, it is important that presenters not tell listeners their framing theory; rather, presenters allow listeners to confer and ask them clarifying questions, and only confirm or deny listeners' guesses. Before moving on to the next

Table 1. Example outcomes from Round 1 in a graduate-level ecology course. Note that framing theories are broadly defined, which allows students with varied levels of ecology experience to be active and equal participants in the exercise.

Primary Framing Theories	
Student 1	Invasion ecology theory (e.g., characteristics that increase invasibility of certain ecosystems and invasiveness of certain species)
Student 2	Climate change theory (e.g., responses of key ecosystem processes [NPP, C sequestration, etc.] to elevated greenhouse gases and changes in climate dynamics)
Student 3	Predator-prey dynamics theory (e.g., population fluctuations owing to predator-prey interactions and resource limitations [Lotka Volterra model])
Fundamental question that integrates all three framing theories	
	When and where do invasive prey species have functional redundancy under changing climate conditions?

presentation, the listeners and presenter must agree on the primary framing theory the presenter used for their project. (*Note*: Some research projects are guided by several framing theories; in this case, the group chooses one.) Requiring presenters and listeners to agree upon framing theories challenges students to better understand how and which theories framed their research. (Our observation is that feedback from peers has helped some students to better understand their own framing theories!)

Once all students in the small group have given their presentations and conducted self-assessment, received and provided peer critique, and decided upon framing theories, the group is charged with generating four fundamental questions that integrate the 3–4 primary theories represented by the group's projects, answers to which would advance scientific theory and understanding (30 minutes) (Table 1). Each small group writes their four fundamental questions legibly on a piece of paper. In addition to generating and recording four fundamental questions, the group also generates and records a "sabotage" question that is different from the other four in some subtle way, in that it does not embody the primary framing theories represented in the projects. Teachers should prompt students to mix the sabotage question in with their other four questions, that is, not necessarily list it as Question 5. After Round 1, students from all small groups return to the large classroom with their five questions in hand for Round 2 (Figure 1).

Round 2: Guessing Each Other's Fundamental and Sabotage Questions

In Round 2, each small group is charged with reading the other groups' fundamental (and sabotage) questions and identifying the framing theories represented in the questions, as well as the sabotage questions. Each group has 10 minutes with each other group's list, during which students write their guesses about the framing theories and sabotage question on a piece of paper, fold it in half so their guesses are not visible, and fasten it to the original list of questions with a paperclip. Small groups pass each list of questions around the room in a clockwise direction until each small group eventually receives its original list with the other groups' guesses fastened to it. Small groups then take turns reading aloud and reporting other groups' guesses about their primary framing theories and sabotage questions. Each group takes a turn verifying (or clarifying) its framing theories, and the teacher projects them for all to see (e.g., through an LCD projector on the wall, writes them on Flip Chart paper, etc.) (Table 2). To amplify student engagement, the teacher may add the element of play by offering "framing theory points" to each group that guesses another group's framing theories correctly, and may offer a final reward to the winning team. In upper-level major or undergraduate courses, offering food (or merely bragging rights) may suffice as motivation to "win," whereas in high school and lower-level, non-major undergraduate courses, the instructor may design a points system to reward student participation and insight. Once all framing theories are recorded visibly, the large group stays together for Round 3: The Meta-Challenge (Figure 1).

Round 3: The Meta-Challenge

In Round 3: The Meta-Challenge, the original small groups are charged with developing *one* fundamental question that integrates *all* framing theories shared by the respective groups. Small groups have 20 minutes to generate their one fundamental question, which the teacher records and projects for all to see (Table 2). A playful addition to this round is to frame it like Fictionary, in which the instructor adds a question of their own and students are challenged to identify which of the questions is actually the teacher's. In this case, the instructor can lead students in a discussion of which question is theirs and how they think it incorporates all the framing theories (Figure 1).

Students are then invited to share their thoughts about the challenges, opportunities, and limitations of generating fundamental questions that integrate numerous, interrelated scientific theories. The discussion is an opportunity to discuss theory advancement, the nature of fundamental questions, and appropriate scaling and

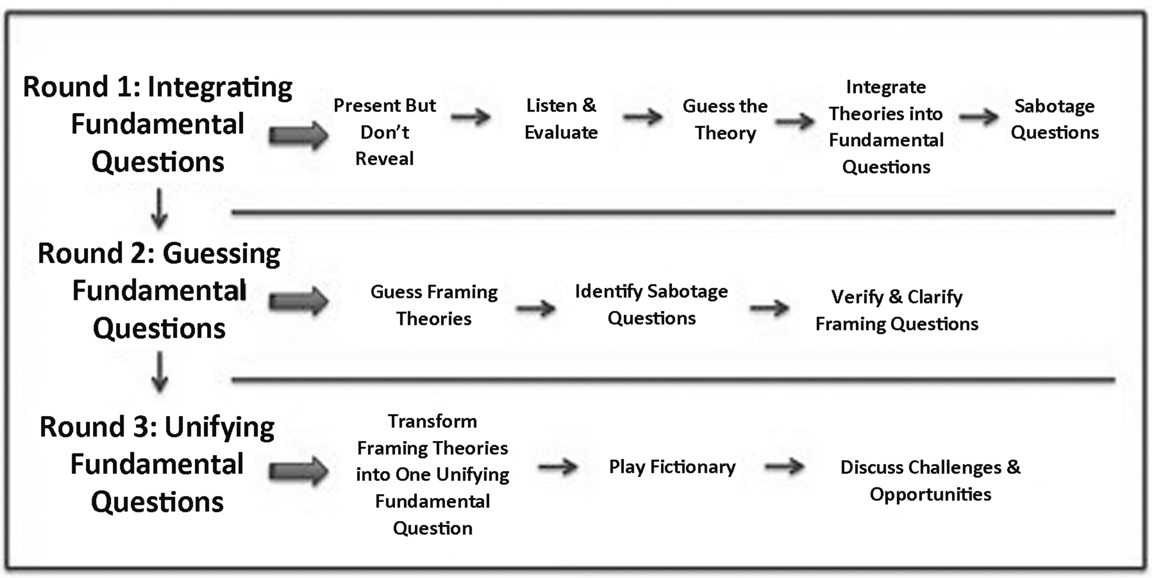

Figure 1. An overview of the Sabotaging Presentations exercise in rounds.

Table 2. List of primary theories represented by semester-long research projects in a graduate-level ecology course (12 students), as well as the four fundamental ecological questions students generated that integrated all theories (Meta-Challenge). Note the breadth of each question, which generates discussion about meaning, scale, and feasibility in research questions and process.

All Bodies of Theory Represented
Hydrology theory
Climate change theory
Disturbance theory
Habitat fragmentation theory
Population ecology theory
Urban ecology theory
Community ecology theory
Resilience theory
Invasion ecology theory
Succession theory
Final Fundamental Questions
What kind of sustainable developments can we invest in that will help our environment adapt to the effects of climate change, locally and globally?
How does sea level rise impact species assemblages in habitats that are hydrologically disconnected due to anthropogenic development, and can environmental restoration projects that reconnect historic hydrology improve species diversity and overall ecosystem services?
Across ecological scales, both natural and human-made, how do the implications of climate change affect natural systems and resource management?
How can ecological science be advanced by understanding the relationships between biota and biogeochemical cycles?

Table 3. Subset of student feedback about the exercise used in a graduate-level, interdisciplinary ecology course.

"It was a great way to synthesize the course concepts. It reinforced for me the essential takeaways of the class: the ecological theories/fundamental questions we'd been grappling with all semester."
"The best part (and the most challenging) was articulating the 'one ecological question to rule them all'—the one question uniting all theories. This was impossible, of course, but what a great way to push against the limits of ecological integration."
"I didn't think of it until just now, but it was as if I'd used Google Earth to shift my perspective about my project—like I'd been zoomed in on my study site for so long that it wasn't until this activity that I'd backed out and gotten the whole planet to fit into the frame again."
"I thought it was really effective and a great way to tie the course together . . . a great opportunity to learn about different methodologies and analytical techniques."

feasibility in scientific research. For example, the teacher may encourage students to compare the scale, relevancy, and feasibility of the final handful of fundamental questions with the original fundamental questions generated by each small group.

○ Application

This exercise is especially useful for upper-level or majors science courses in which students are charged with understanding and applying scientific methods, designing, executing, and sharing independent research projects, and unifying theory and practice. Student feedback about the exercise in our course indicates that it deeply engages them with one another's presentations and with course content, and that it is useful in reinforcing the importance of using framing theory to guide research and advance scientific integration and understanding (Table 3). The exercise may be used in various subdisciplines of biology, providing the subdiscipline has sufficient breadth in framing theories (Table 4).

Table 4. Examples of framing theories that may be used in subdisciplines of biology other than ecology. Teachers who use this exercise will need to familiarize themselves with prevailing theories in their disciplines. Whether theories are currently supported is not necessarily relevant; as long as students are using the theories to frame their research questions, teachers can assess the student learning outcomes detailed above.

Course title or topic	Possible framing theories			
Research Techniques	Positivist	Post-positivist	Constructivist	Critical theory
Genetics	Multilevel selection	Niche construction	Epigenetics	Evolvability
Evolution	Lamarckian inheritance	Darwin's Theory of Natural Selection	Epigenetics	Evolvability
Geology	Gradualism	Catastrophism	Plate tectonics	Expanding Earth
Physics	Quantum mechanics	General relativity	String theory	M-theory

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