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Synthesizing Science

Loren B. Byrne

Students engage in the work of scientists by summarizing research articles, collaboratively writing synthetic abstracts, and proposing questions for further inquiry.

Writing Focus: *sources, motive, analysis*
Teacher Preparation: *medium*
Student Preparation: *high*
Estimated Time: *50 minutes*
General Discipline: *sciences*

EXERCISE

Prep Work: Identify a topic (general or narrow) amenable to having students locate, read, summarize, present, and synthesize peer-reviewed articles. A controversial topic or one that can be analyzed from diverse perspectives works particularly well because many articles will be needed to understand it in a holistic way. (In my courses, I have used natural selection, food webs, water pollution, amphibian declines, green roofs, and the effects of earthworms on soil.) The exercise's general structure is a modification of the "jigsaw" technique, as described at www.jigsaw.org.

For homework, ask each student to find a peer-reviewed article relevant to the focal topic. Beginning students may need additional help to find and assess scholarly articles, such as a lesson about how to use library databases or other search engines. Have each student email you a properly formatted bibliographic reference of the article for approval. This allows you to ensure that everyone has a relevant, useful, and unique article (though uniqueness matters less in large classes if students will present the same article in separate groups). Emphasizing proper formatting reinforces the professional practice of paying attention to details when preparing reference lists. Be sure to assign this search-and-approval step well before the class meeting because students may need to find an alternative article if their first choice is taken or inappropriate for the exercise.

Before class, have students prepare short presentations about their articles, focusing on the research question, a brief summary of methods and results, the conclusion, and the broader scientific or social significance. Share strategies with students in advance about how to read scientific articles (for example, encourage them to identify the one essential point from each section). Reassure less-experienced students that research articles can be difficult for even professional scientists; and that it's okay not to understand all the technical terms or details, especially of methods and statistics. To facilitate presentations, ask students to prepare formal notes or slides (see below). Finally, to guide students' in-class work, create a handout with prompts, like the "Worksheet Prompts" from step four below.

Step One: (5 minutes) Introduce the exercise by emphasizing how synthesizing "the literature" is essential to the work of scientists. In this context, synthesis refers to the process of bringing together information from different articles to generate emergent insights. Share upfront with students the purpose of the exercise: their presentations will enable them to gain a more holistic understanding of the topic, generate connections among the results of different studies, and ask better questions for future research. Note that professional scientists complete these essential tasks when writing grant proposals and manuscripts.

Step Two: (30 minutes) The format and time allotted for student presentations are flexible—a function of class size, meeting duration, and instructor preferences. In smaller classes (ten students or fewer), have each student present to the whole class for three to five minutes, either informally without handouts or more formally with one or two summary slides. In larger classes (more than ten students), consider creating small groups of four to six in which students present only to their fellow group members. To ensure sustained attention during the presentations and to prepare for synthesis work, ask students to record summative notes about, and in-text citations for, the presented articles (worksheet prompt 1 below).

Step Three: (15 minutes) In pairs (or in small presentation groups), have students discuss and integrate information from across the articles to draft a synthetic abstract (prompt 2 below). If your students are unfamiliar with synthetic abstracts, you might consider providing them with a one-paragraph model on a different topic. Remind them of the importance of proper attribution, which dictates the inclusion of properly formatted in-text citations in this paragraph. Reconvene the class to compare main points from their abstracts and discuss missed or underemphasized relationships and synthetic insights.

Step Four: (15–20 minutes, optional) If time permits—or for homework—have students respond to prompts 3–6, which ask them to brainstorm and generatively write about follow-up questions, hypotheses, future research, and personal reflections, all inspired by the set of articles. In the same or next class, students can share some of their ideas, which can facilitate further discussions about synthesizing science.

REFLECTIONS

Many students do not realize how important reviewing the literature and writing effectively are to the work of scientists (both are absent from simple models of "the scientific method"). They often find themselves challenged by the tasks of conducting rigorous literature searches, reading and synthesizing multiple articles, and writing in the science genre. Repeated practice of these tasks, including with peers, can help improve students' abilities and confidence. When using this exercise, I emphasize that "this is what real scientists do" and that it is not "busy work." Further, the exercise reflects the collaborative nature of contemporary science, which requires skills for interpersonal communication and co-creation of synthesized knowledge through presentations, discussion, and writing.

I have found the exercise to be pedagogically valuable both because it is easily modified (for varied topics, it can be shortened or extended) and because it helps introduce variety into a series of lecture-heavy class days. It can be used in many course contexts, from introductory through advanced; from narrowly focused through broadly interdisciplinary; in lecture, laboratory, and seminar formats; and with enrollments of many sizes. A variety of follow-up assignments could be used: students might draw concept maps to illustrate connections across and locate gaps within the literature; extend their review with a more targeted search of articles; prepare an annotated bibliography; or write a formal literature review paper.

In one particularly successful iteration, I used the exercise in an introductory biology lab in which students worked in pairs to choose and present an article about the ecology and evolution of cardinals. As part of the lesson, I introduced the idea of the literature and walked students through the search process, subsequently providing guidance and approving articles for presentations as they searched during class time. Because this was some students' first time presenting an article, I gave them an explicit outline requiring five slides—for 1) introduction, 2) question and hypothesis, 3) methods, 4) results, and 5) conclusion—which reduced their anxiety. To emphasize that giving and accepting constructive, peer-review comments are essential parts of science, these students were asked to offer immediate oral feedback on each other's presentations. The approach worked extremely well with high levels of engagement from many students; in part, I think this was helped by my explicit creation of a safe space, making it clear that all students would be equally critiqued because everyone (including me) can improve their communication skills. After the presentations, most students were able successfully to complete the worksheet and seemed to enjoy the process of critical reflection and asking follow-up questions. For a few, the exercise generated valuable just-in-time teaching moments, such as discussing how to do synthesis when one student admitted that she didn't understand what was expected.

Another option, if you are emphasizing course content over research skills, is to choose the articles yourself, or to use non-peer-reviewed texts (newspaper and magazine articles, or websites). I used these approaches in an introduction to a sustainability studies course, with many nonscience students, to explore the topic of lawn and garden ecology and management. By simplifying the exercise, I found that students were readily able to achieve the desired synthesis goals, which may not have been possible if they became overwhelmed by the unfamiliar tasks of locating and reading science articles. This variation can also be used to emphasize the need to evaluate the quality and reliability of popular press articles and websites (for example, websites authored by lawn chemical companies).

In summary, I have found that this exercise accomplishes several learning goals at once. It fosters rewarding student-generated discussions and connections (many of which I would not have included in a lecture). It helps students recognize the importance of reviewing the literature and of collaboration as essential parts of "doing science." Perhaps most importantly, it creates dynamic learner-centered classrooms in which students improve both their synthesizing and scientific writing skills.

HANDOUT

Synthesizing Science Worksheet

1. Lit Review & Summary: Record a summative take-home message (2–3 sentences) and in-text citation (for example, author and year format) for each presented article.
2. Synthesizing Science: What can be learned from this group of articles? Write a synthetic abstract (one paragraph) that identifies connections among the articles. What are the similarities and differences across the studies? How does the information from each relate to the others? What insights emerge from bringing them together that would be missed with just one article? Include properly formatted in-text citations to identify the sources for each sentence.
3. New Questions: Using the presented articles as inspiration, write three follow-up questions to guide future research about the topic.
4. Hypothesis Formation: Choose one of the questions and write an (alternative) hypothesis about expected results that you predict to find with additional research. Why do you expect those findings?
5. Hypothesis Testing: What could be done to investigate your hypotheses? Describe a field experiment or observational study that could be conducted to test your hypothesis. Identify as many essential methodological details as you can.
6. Reflection: Take a moment to reflect on what you've learned. What new insights have you gained about the topic and value of reading and synthesizing peer-reviewed literature as a part of scientific research? Be as specific as you can.