Collaborative learning – a jigsaw

Christopher Finelli[1], Diane Ebert-May[2], and Janet Hodder[3]

Reading and understanding primary research literature is a challenge for students as they can be intimidated by scientific jargon and the unfamiliar style of scientific prose (Epstein 1972; White 2001). It is, however, an important skill that should be developed well before they graduate. Students' abilities to accomplish this are often underestimated, especially in the case of nonscience majors who are capable of reading the biological literature and of approaching it critically (Gillen *et al.* 2004). The paper by Fang *et al.* (pp 186–192) provides an example of how to bring primary literature into both large and small classes, using a cooperative learning strategy known as a "jigsaw".

Although over 600 experimental and 100 correlational studies indicate that cooperative learning promotes higher achievement (Springer *et al.* 1999; Johnson *et al.* 1998), faculty are often wary about implementation in large classes, where logistics are a challenge and poor attendance can hinder group work. In practice, cooperative learning techniques encourage class attendance and participation (Ebert-May *et al.* 1997). For cooperative learning to be most effective, faculty need to understand the techniques and students need directions and practice of the skills necessary for effective group work (Maloof 2005). The jigsaw strategy for cooperative learning may be most effective by mid to late semester (see NISE 2005), especially in large classes.

We model two ways to implement a jigsaw; the first is based on the components of the research paper and the second is derived from concepts presented in the paper. Practice using this technique will advance students' abilities to read research and understand the concepts of the paper better than when the paper is explained by the instructor, or when students are asked to read a paper individually for class discussion.

Student goals

- Gain understanding of the content of a primary research article
- Demonstrate expertise in reading and interpreting scientific literature
- Build high-quality interactions with their peers
- Transfer the knowledge and skills about science as a process to other research papers

Instructor goals

- Use jigsaw as a strategy for cooperative learning
- Facilitate students' understanding of complex material in scientific literature

[1]Louisiana Universities Marine Consortium, [2]Michigan State University, [3]University of Oregon

Implementing jigsaws

Students must be comfortable and effective with group work to use jigsaws in large classes. At the beginning of the semester, students form permanent groups composed of four or five students. Everyone reads the entire paper as homework, but each student in a group becomes an "expert" on part of the paper. During the next class session, all the experts for each section of the paper meet, share their knowledge, and clarify their understanding. After 15 minutes, groups reform and discuss the paper. All members of the group learn from each other and put together different parts of the paper. For variations on this approach refer to the National Institute for Science Education (NISE) website. The jigsaw can be logistically challenging, but it enables faculty to decrease the "functional" size of a large class to small groups of students.

Choosing the right paper

Choice of primary research to read in class is critical. Papers should reflect central themes within the discipline and be easily understood by the students. For example, Fang *et al.* is an original research paper with conceptually simple methods (quantifying wetland loss by comparing maps). Fang *et al.* touch on central issues in ecology, such as biodiversity and ecosystem services, and this paper may be best suited for an advanced environmental science course. However, the jigsaw technique can be applied to any research paper.

Jigsaw 1. Using components of the paper

The first jigsaw focuses on dissection of the paper into component parts: abstract and introduction, methods, results and discussion. The leading questions in Panel 1 serve to further guide experts in each group.

Jigsaw 2. Using content themes

An alternative jigsaw technique is to dissect a paper using content that relates to the learning goals of a course. Each student takes a topic, and an understanding of the paper is gained through discussion of the following:

- Wetland conversion (impoldering): Why? How? Benefits or negative impacts?
- Ecosystem goods and services: What are they? Why are they important?
- Biodiversity: What is it? How is it measured? Why is it important?

Assessment of jigsaws

Assessment of a jigsaw in a large class becomes manageable by assessing some components as group work (which measurably reduces the volume of grading) and other components as individual work. Panel 2 is a rubric that explains the ideal expert understanding students should gain from

Panel 1. Guiding questions for expert groups

- *Abstract and Introduction:* What broad disciplinary topic does the paper address? Why was the research conducted? What is the authors' primary hypothesis? Are there any terms you do not understand?
- *Methods:* When and where was the research conducted? What techniques are used to gather data? How were the data analyzed? Do any methods require further explanation?
- *Results:* What are the primary findings or trends? Are the conclusions supported by the data? Were any findings not expected by the authors? What were effective ways of presenting the results, and what ways were less effective?
- *Discussion:* Was the primary hypothesis supported? Were there any unexplained results? Do authors suggest future research? What alternative conclusions are explored?

For a similar approach, see: http://helios.hampshire.edu/~apmNS/design/RESOURCES/HOW_READ.html

Jigsaw 1 and can be used in a variety of ways. It could be given to groups as a way to self-check their understanding of the paper. Or the expert on the section in each group could write a summary of the section, based on the guiding questions in Panel 1; the rubric is then used to assess these summaries. Responses are evaluated in terms of the specific student objectives and the degree to which students achieved understanding in comparison to the ideal response. A similar rubric can be constructed for Jigsaw 2. Other assessments could include asking students to design the next possible research questions and methods for one of the topic areas. Or, as we have suggested in previous Pathways articles, students can develop models (box models, concept maps) that illustrate the interconnections of concepts in the paper.

Panel 2. Rubric for ideal understanding of Fang *et al.*

Abstract and Introduction: Expert groups should identify the primary hypothesis that wetland loss resulted from impoldering, connect biodiversity and ecosystem services as important topics in ecology, and define impoldering as a technique of wetland conversion.

Methods: Expert groups should explain that Fang *et al.* analyzed the changes in number and coverage of lakes > 1 km^2, identify the location of the study as Jianghan Plain, southeastern China, and the temporal span as 1950s–1998, and identify the use of remote sensing and historical maps. Advanced student experts should note that the authors resampled their data to standardize spatial resolution, and also standardized the season from which images were chosen.

Results: Expert groups should identify the substantial reduction in the number and coverage of lakes from the 1950s to 1978 and a reversal of this trend between 1978 and 1998. They should explain the presence of anomalous results, such as the increase in the number and area of lakes in the 200–500 km^2 class between 1950s and 1978 and the decrease in number and area of small lakes (1–5 km^2) from 1978 to 1998. Students should convey this to their peers using the figures and tables.

Discussion: Expert groups should convey the primary conclusion that lake loss in the 1950s and 1960s resulted from extensive draining of lakes to increase agricultural production, and should explain that the increase in the number and area of lakes from 1978 to 1998 resulted from a change in government policy. They should note that the alternative hypothesis that changes in wetlands resulted from climatic shifts during the same time period is rejected. Finally, students should note that biodiversity and ecological services have not returned to their past levels.

Assessment of knowledge transfer and group dynamics

The principles of cognitive science and learning theory indicate that information learned in one context will transfer to a different context if we teach in ways that encourage transfer (Halpern 2004). Students' ability to transfer knowledge and skills from this exercise can be assessed in numerous ways by assigning another paper or sections of a paper. The questions in Panel 1 can be used to assess students' understanding of any research paper through quizzes or short writing assignments.

Finally, assessment of group dynamics provides important feedback to students and instructors. Individuals within groups comment on quantity (percent contribution) and quality (written comments) of each other's contributions. The instructor collects these by group and provides general feedback to the entire class about trends, or specific feedback to less functional groups.

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