Analyzing results: the tip of the iceberg

Diane Ebert-May[1], Everett P Weber[1], Janet Hodder[2], and Janet M Batzli[3]

As faculty dive deeper into educational research, accountability, reliability, and validation will push them to analyze their classroom data in more objective ways. In the May issue of *Frontiers*, we described two research designs appropriate for classroom research – multiple group and split-group comparisons. We used an example to analyze how students approach an ill-structured problem (Ebert-May *et al.* 2006). Here, in the final article in this series, we use assessment data from a single course in which we conducted a pilot study to illustrate an approach to research design and analysis. We begin by describing the human subject approval for research and then show the initial analysis of results from the study that led to further investigation. As a final note, we offer ideas about the needs and directions of future ecological education research.

Human subject approval of research

Reasons for pursuing research into undergraduate learning depend on faculty goals, time, energy, and support (Batzli *et al.* 2006). Regardless of the reason, faculty are responsible for becoming knowledgeable about conducting research on human subjects and abiding by federal regulations and policies, as implemented by their institutions. At universities and colleges, institutional review boards protect the rights, welfare, and privacy of human subjects who participate in research conducted by students and/or faculty.

Question

In previous *Pathways* articles (October 2004, March 2005, April 2005) we used concept maps to show how students can visualize their thinking by building models that enable them to arrange concepts hierarchically and connect new concepts to those based on prior knowledge (Novak 1998). Concept maps are useful tools that enhance meaningful learning and retention by allowing students to practice making connections among concepts (Ausubel 2000). We designed this pilot study to test whether students who practiced using concept maps performed better on assessments designed to detect their ability to make connections than students who used another instructional tool. We implemented the use of these tools in units on evolution, invasive species/ecosystem services.

Research design

We chose the split-group design, randomly dividing the class into two groups (A and B). For treatments, we asked students to perform multiple representations (MRs) of concepts, a task similar to concept maps. In MRs, students define each concept and then provide an example, an analogy, and a drawing or equation illustrating the concept. Students are not asked to make connections among concepts in MRs, whereas students that constructed concept maps specifically focused on making such connections. We believe that both concept maps and MRs are ways to illustrate "model-based reasoning" skills, a term referring to everything from mental models to expert consensus models (Clement 2000). Assigned homework provided both groups with comparable tasks that required about the same time to complete.

Following a unit of instruction on evolution, all students were given concepts and randomly assigned to make either concept maps (Group A) or multiple representations (Group B) for homework (Panel 1). Each assignment was graded and returned to the student, with the option of revising. The first mid-term exam included questions about evolution. Topics during the next unit of instruction included invasive species and ecosystem services. Again, all students were given concepts to make models, and this time the groups' tasks were switched: Group A made MRs while Group B made concept maps. Students then received feedback and had the option of revising their models. The second mid-term exam included questions about invasive species and ecosystem services.

Results and analysis

Since the number of questions differed between Exams 1 and 2, we standardized exam scores by converting each to percent correct. In addition to the dependent variable (standardized exam score) and the treatment (concept map versus MR), the design includes trial (Exam 1 vs Exam 2) as a nuisance variable (an undesired source of variation).

The statistical model for the split-group design incorporated trial as a repeated measure crossed with treatment. The resulting ANOVA table has three effects: treatment (concept maps versus MRs), trial (Exam 1 or Exam 2), and the interaction of treatment by trial. If treatment was significant and the interaction was not significant, concept maps made a substantial difference in student performance on exam questions. If the trial was significant but treatment was not, students performed better on one test than the other. If the interaction was significant, regardless of the significance of treatment and trial alone, there may be a more complicated pattern to explain and further analysis is required. The results indicated "no difference" between the effect of concept maps or MRs in terms of students' understanding of evolution, invasive species/ecosystem services, as indicated by their scores on assessment questions (Panel 1). Based on our results, we rejected the hypothesis

---

[1] *Michigan State University*, [2] *University of Oregon*, [3] *University of Wisconsin*

Panel 1. Split-group study design and results

The split-plot repeated measures ANOVA (df = 1, 38) showed no significant effect for treatment (f = 0, *P* = 0.95), trial (f = 0.21, *P* = 0.65), or the interaction of treatment by trial (f = 3.0, *P* = 0.58). SAS proc mixed was used for analysis.

Instructional unit	*Group A* (*n* = *18*)	*Group B* (*n* = *21*)	*Assessment*	*# Questions*
Evolution[1]	Concept map 76 (± 2.5)[3]	MR[4] 77 (± 2.4)	Exam 1	14 MC[5] 12 ER[6]
Invasive species[2]/ Ecosystem services	MR 75 (± 3.0)	Concept map 77 (± 2.8)	Exam 2	1 MC 8 ER

[1] First unit of instruction, homework, and exam (time = 1); [2] Second unit of instruction, homework, and exam (time = 2); [3] Mean percent correct on exam (± standard error); [4] MR = multiple representations; [5] MC = multiple choice questions; [6] ER = extended response questions (written short answer)

that concept maps help students perform better on contextual assessments than MRs.

Next steps

Both concept maps and MRs require critical thinking, and assessments suggest that both tools affect student learning in similar ways and have value in active learning classrooms. Given that we found no difference in the pilot study, what is the added value of these instructional tools? The next steps in our research include using discriminate analysis to see if concept maps or MRs help students answer some types of questions better than others, and refining the rubrics for the extended response questions to identify where students made connections. Building on this information, we will balance the number of questions for each treatment with respect to format, conceptual level, and number of questions, and increase power and external validity by performing the study in numerous semesters of the course. Experimental designs cannot tease out the effect of multiple factors that play into an *individual* students' conceptual change, but experimental designs that take into consideration the context of the classroom, instructional design, students' prior knowledge, and how students use multiple learning strategies *can* provide insight about how a *population* of students learn science best.

Final note

This article touched only the tip of the iceberg of possible questions to investigate how students learn science best. One avenue for research in science education is model-based learning that stems from the emerging theory of conceptual change (Strike and Posner 1992; Clement 2000). The use of inquiry-based, active learning strategies in classrooms leads to questions about students' conceptual models that promote "conceptual understanding" in science at a level that goes beyond memorization of facts, equations, or procedures. Investigation of questions such as, "What is the role of mental models in science learning?", "What learning processes are involved in constructing them, and what teaching strategies can promote these learning processes?", could make important contributions to theories of instruction and provide practical applications.

Studies conducted about teaching and learning using large sample sizes and quantitative study designs will enable scientists to critically examine and report their students' achievements in response to innovations in their courses. During this process, studies on faculty professional development (including graduate and postdoctoral students) will contribute to our understanding of how and why people, departments, and institutions change. Seymour *et al.* (2005) addressed the role teaching assistants (TAs) play as partners in innovation and provided an analysis of TAs responses to new pedagogies and their need for professional development. Moving ecology education research forward requires a community of investigators who collaborate to solve complex problems (D'Avanzo 2003).

Beginning in August 2004, our intent was to provide examples of how to use active, inquiry-based teaching in large (and small) enrollment courses, how to assess the impact of teaching innovations on student learning, and how assessment data could drive subsequent decisions about instruction. Beginning in March 2006, we have attempted to bridge the pathway from instruction to research and to encourage instructors to make their teaching and inquiry into students' learning visible. The *Pathways* series engaged the expertise of faculty from throughout the US in the development, writing, and peer review of these articles. Without their contributions, this series would have ended long before now. As we contemplate and implement future research on scientific teaching, we note that successful people are the ones who take advantage of those around them to ultimately benefit students.

Acknowledgements

We thank the National Science Foundation for their long-term support of the FIRST project, Faculty Institutes for Reforming Science Teaching (DUE 0088847) and all faculty and graduate students who contributed to these papers. All *Pathways* papers are peer reviewed.

References

Ausubel DP. 2000. The acquisition and retention of knowledge: a cognitive view. Boston, MA: Kluwer Academic Publishers.

Batzli, JM, Ebert-May D, and Hodder J. 2006. Bridging the pathway from instruction to research. *Front Ecol Environ* **4**: 105–07.

Clement J. 2000. Model based learning as a key research area for science education. *Int J Sci Educ* **22**: 1041–53.

D'Avanzo C. 2003. Research on learning: potential for improving college ecology teaching. *Front Ecol Environ* **1**: 533–40.

Ebert-May D, Batzli JM, and Weber EP. 2006. Designing research to investigate student learning. *Front Ecol Environ* **4**: 218–19.

Novak JD. 1998. Learning, creating, and using knowledge: concept maps as facilitative tools in schools and corporations. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Seymour E, Melton G, Wiese DJ, and Pedersen-Gallegos L. 2005. Partners in innovation: teaching assistants in college science courses. Lanham, MD: Rowan and Littlefield Publishers, Inc.

Strike KA and Posner GJ. 1992. A revisionist theory of conceptual change. Albany, NY: State University of New York Press.