STEM Topic: Laboratory instruction, laboratory projects

Brickman, P., Gormally, C., Armstrong, N., Hallar, B. 2009. Effects of inquiry-based learning on students' science literacy skills and confidence. International Journal for the Scholarship of Teaching and Learning. Vol. 3, 22.

> Calls for reform in university education have prompted a movement from teacher- to student-centered course design, and included developments such as peer-teaching, problem and inquiry-based learning. In the sciences, inquiry-based learning has been widely promoted to increase literacy and skill development, but there has been little comparison to more traditional curricula**.** In this study, we demonstrated greater improvements in students' science literacy and research skills using inquiry lab instruction. We also found that inquiry students gained self-confidence in scientific abilities, but traditional students' gain was greater –likely indicating that the traditional curriculum promoted over-confidence. Inquiry lab students valued more authentic science exposure but acknowledged that experiencing the complexity and frustrations faced by practicing scientists was challenging, and may explain the widespread reported student resistance to inquiry curricula.

Park Rogers, M.A., Abell, S.K., 2008. The design, enactment, and experience of inquiry-based instruction in undergraduate science education: A case study. Wiley Periodicals, Inc. Science Education. Vol. 92, 591-607.

> The purpose of this study was to understand one case of undergraduate inquiry-based instruction through the words and actions of students and instructors. The data sources included fieldnotes from 16 of 29 classes, two sets of student and instructor interviews (beginning and end of the semester), and a collection of artifacts, such as the laboratory manual, lecture handouts, and the course syllabus. The participants for this study included four faculty instructors and two purposively selected student groups, totaling eight students. We found the instructors' two course goals, (a) teaching students how scientists do science and (b) using an interdisciplinary approach to develop students' content knowledge of the big ideas in science, were consistent with our observations and the students' descriptions of their experience in the course. However, we observed, and the students also noted, an important feature of the course that the instructors did not describe as a course goal was its reliance on the social nature of learning. This telling case demonstrates that inquiry-based instruction is achievable in undergraduate science education. Implications are discussed for college science instructors interested in inquiry teaching

Quitadamo, I.J., Kurtz, M.J. 2007. Learning to improve: Using writing to increase critical thinking performance in general education biology. Life Sciences Education. Vol. 6, 140-154.

> Increasingly, national stakeholders express concern that U.S. college graduates cannot adequately solve problems and think critically. As a set of cognitive abilities, critical thinking skills provide students with tangible academic, personal, and professional benefits that may ultimately address these concerns. As an instructional method, writing has long been perceived as a way to improve critical thinking. In the current study, the researchers compared critical thinking performance of students who experienced a laboratory writing treatment with those who experienced traditional quiz-based laboratory in a general education biology course. The

effects of writing were determined within the context of multiple covariables. Results indicated that the writing group significantly improved critical thinking skills whereas the nonwriting group did not. Specifically, analysis and inference skills increased significantly in the writing group but not the nonwriting group. Writing students also showed greater gains in evaluation skills; however, these were not significant. In addition to writing, prior critical thinking skill and instructor significantly affected critical thinking performance, whereas other covariables such as gender, ethnicity, and age were not significant. With improved critical thinking skill, general education biology students will be better prepared to solve problems as engaged and productive citizens.

Rath, K.A., Peterfreund, A.R., Xenos, S.P., Bayliss, F., Carnal, N. 2007. Supplemental instruction in introductory biology I: Enhancing the performance and retention of underrepresented minority students. Life Sciences Education. Vol. 6, 203-216.

Supplemental instruction classes have been shown in many studies to enhance performance in the supported courses and even to improve graduation rates. Generally, there has been little evidence of a differential impact on students from different ethnic/racial backgrounds. At San Francisco State University, however, supplemental instruction in the Introductory Biology I class is associated with even more dramatic gains among students from underrepresented minority populations than the gains found among their peers. These gains do not seem to be the product of better students availing themselves of supplemental instruction or other outside factors. The Introductory Biology I class consists of a team-taught lecture component, taught in a large lecture classroom, and a laboratory component where students participate in smaller lab sections. Students are expected to master an understanding of basic concepts, content, and vocabulary in biology as well as gain laboratory investigation skills and experience applying scientific methodology. In this context, supplemental instruction classes are cooperative learning environments where students participate in learning activities that complement the course material, focusing on student misconceptions and difficulties, construction of a scaffolded knowledge base, applications involving problem solving, and articulation of constructs with peers.

McConnell, D.A., Steer, D.N., Owens, K.D., Knott, J.R., Van Horn, S., Borowski, W., Dick, J., Foos, A., Malone, M., McGrew, H., Greer, L., Heaney, P.J. 2006. Using conceptests to assess and improve student conceptual understanding in introductory geoscience courses. Journal of Geoscience Education. Vol. 54, 61-68.

Conceptests are higher-order multiple-choice questions that focus on one key concept of an instructor's major learning goals for a lesson. When coupled with student interaction through peer instruction, conceptests represent a rapid method of formative assessment of student understanding, require minimal changes to the instructional environment and introduce many of the recognized principles of effective teaching that enhance student learning. In this study, instructors from several different institutions developed over 300 conceptests for the geosciences. These instructors then used this suite of concept questions in a wide range of classroom settings, including large introductory general education Earth Science courses for non-majors at open enrollment institutions, smaller physical geology classes suitable for majors at private colleges, and in introductory geology laboratory settings. Results of pre- and post-class Geoscience Concept Inventory (GCI) testing and qualitative feedback from students and instructors showed that conceptests increased attendance, improved student satisfaction, and enhanced student achievement. Participating instructors found implementation of conceptests into their classes straightforward and required less than 30 minutes of preparation per class. The conceptest question database is available on-line for geoscience instructors.

DeHaan, R.L. 2005. The impending revolution in undergraduate science education. Journal of Science Education and Technology. Vol. 14, 253-270.

There is substantial evidence that scientific teaching in the sciences, i.e. teaching that employs instructional strategies that encourage undergraduates to become actively engaged in their own learning, can produce levels of understanding, retention and transfer of knowledge that are greater than those resulting from traditional lecture/lab classes. But widespread acceptance by university faculty of new pedagogies and curricular materials still lies in the future. In this essay we review recent literature that sheds light on the following questions:

• What has evidence from education research and the cognitive sciences told us about undergraduate instruction and student learning in the sciences?

• What role can undergraduate student research play in a science curriculum?

• What benefits does information technology have to offer?

• What changes are needed in institutions of higher learning to improve science teaching?

We conclude that widespread promotion and adoption of the elements of scientific teaching by university science departments could have profound effects in promoting a scientifically literate society and a reinvigorated research enterprise.

Kardash, C.M., Wallace, M.L. 2001. The perceptions of science classes survey: What undergraduate science reform efforts really need to address. Journal of Educational Psychology. Vol. 93, 199-210.

Nine-hundred twenty two undergraduates completed an 80-item survey that assessed their perceptions of undergraduate science classes. Factor analysis of the items yielded 6 factors: (1) Pedagogical Strategies, (2) Faculty Interest in Teaching, (3) Student Interest and Perceived Competence in Science, (4) Passive Learning, (5) Grades as Feedback, and (6) Laboratory Experiences. Women differed significantly from men on the Pedagogical Strategies, Passive Learning, Grades as Feedback, and Laboratory Experiences factors. Correlational analyses and evidence from distinct groups supported the survey's construct validity. Students reported room for improvement of the science faculty's pedagogical practices. From the students' perspective, how information is taught appears to be at least as much of a concern as what information is taught.

Musheno, B.V., Lawson, A.E. 1999. Effects of learning cycle and traditional text on compreshension of science concepts by students at differing reasoning levels. Journal of Research in Science Teaching. Vol. 36, 23-37.

Research has found the learning cycle to be effective for science instruction in hands-on laboratories and interactive discussions. Can the learning cycle, in which examples precede the introduction of new terms, also be applied effectively to science text? A total of 123 high school students from two suburban schools were tested for reasoning ability, then randomly assigned to read either a learning cycle or traditional text passage. Immediate and delayed posttests provided concept comprehension scores that were analyzed by type of text passage and by reasoning level. Students who read the learning cycle passage earned higher scores on concept comprehension questions than those who read the traditional passage, at all reasoning levels. This result supports the hypothesis that reading comprehension and scientific inquiry involve similar information-processing strategies and confirms the prediction that science text presented in the learning cycle format is more comprehensible for readers at all reasoning levels.

Webster, T.J., Hooper, L. 1998. Supplemental instruction for introductory chemistry courses. Journal of Chemical Education. Vol. 75, 328-332.

The lack of conceptual understanding of chemistry principles mentioned above has been vastly researched, yielding positive results when direct team learning methods were introduced into the chemistry lecture (*2–5, 9, 10*). Our approach was to utilize the same team learning methods but not to disrupt the lecture format. In this study, the lecture, recitation, and laboratory structure were maintained, but one additional review opportunity was offered to the students: Supplemental Instruction (SI). SI is an interactive program developed in 1979 by Deanna Martin at the University of Missouri–Kansas City, with the goal of helping students achieve mastery of course content while they develop and integrate effective learning and study skill strategies (Martin, D. C. *Supplemental Instruction Training Manual*, unpublished results). Here, SI was utilized as an interactive learning approach to combat the features of traditional algorithmic chemistry teaching techniques, with the hope of increasing the conceptual knowledge and retention rate of introductory chemistry students. By increasing students' conceptual knowledge and thus interest in the class, a reduction in attrition should follow. The limited available literature on this topic illustrates that SI has been successfully implemented into university general chemistry courses (*10, 11*).