

STEM Topic: Large introductory classes

Deslauriers, L., Schelew, E., Weiman, C. 2011. Improved learning in a large-enrollment physics class. *Science*. Vol. 332, 862-865.

We compared the amounts of learning achieved using two different instructional approaches under controlled conditions. We measured the learning of a specific set of topics and objectives when taught by 3 hours of traditional lecture given by an experienced highly rated instructor and 3 hours of instruction given by a trained but inexperienced instructor using instruction based on research in cognitive psychology and physics education. The comparison was made between two large sections (N = 267 and N = 271) of an introductory undergraduate physics course. We found increased student attendance, higher engagement, and more than twice the learning in the section taught using research-based instruction.

Haak, D.C., Hillerislanders, J., Pitre, E., Freeman, S. 2011. Increased structure and active learning reduce the achievement gap in introductory biology. *Science*. Vol. 332, 1213-1230.

Science, technology, engineering, and mathematics instructors have been charged with improving the performance and retention of students from diverse backgrounds. To date, programs that close the achievement gap between students from disadvantaged versus nondisadvantaged educational backgrounds have required extensive extramural funding. We show that a highly structured course design, based on daily and weekly practice with problem-solving, data analysis, and other higher-order cognitive skills, improved the performance of all students in a college-level introductory biology class and reduced the achievement gap between disadvantaged and nondisadvantaged students—without increased expenditures. These results support the Carnegie Hall hypothesis: Intensive practice, via active-learning exercises, has a disproportionate benefit for capable but poorly prepared students.

Halcrow, C., Liams, M. 2011. You can build it, but will they come? *Primus*. Vol. 21, 323-337.

Studies show that more students fail or withdraw from college mathematics courses than any other. To address this concern, the Mathematics Department at the University of North Dakota opened its Mathematics Learning Center (MLC) in the fall of 2000. In this study, the effectiveness of the MLC and the free tutoring offered for students in freshman level mathematics courses was examined.

The quantitative portion of the study examined the difference between course grades in experimental and control sections of four distinct freshman level mathematics courses. Students in the experimental sections were required to attend the Mathematics Learning Center (MLC) for one hour weekly while students in the control sections were simply informed of the availability of tutoring in the MLC. The qualitative portion of the research utilized methodologies of a phenomenological study through in-depth interviews with 13 participants. Three conclusions are offered: 1) Lower level or lower ability students are less likely to attend the MLC and seek help from tutors; 2) Once students got over their fears of engaging with tutors, they found them friendly and helpful, and believed they had greater success because of the tutoring; and 3) A positive correlation existed between time spent in the MLC and course grade for experimental section students.

Kalman, C.S. 2011. Enhancing students' conceptual understanding by engaging science text with reflective writing as a hermeneutical circle. *Science and Education*. Vol. 20, 159-172.

Students can have great difficulty reading scientific texts and trying to cope with the professor in the classroom. Part of the reason for students' difficulties is that for a student taking a science gateway course the language, ontology and epistemology of science are akin to a foreign culture. There is thus an analogy between such a student and an anthropologist spending time among a native group in some remote part of the globe. This brings us naturally to the subject of hermeneutics. It is through language that we attempt to understand an alien culture. The hermeneutical circle involves the interplay between our construct of the unfamiliar with our own outlook that deepens with each pass. It can be argued that for novice students to acquire a full understanding of scientific texts, they also need to pursue a recurrent construction of their comprehension of scientific concepts. In this paper it is shown how an activity, reflective-writing, can enhance students' understanding of concepts in their textbook by getting students to approach text in the manner of a hermeneutical circle. This is illustrated using studies made at three postsecondary institutions.

Marotta, S.M., Hargis, J. 2011. Low-threshold active teaching methods for mathematic instruction. *Primus*. Vol. 21, 377-392.

In this article, we present a large list of low-threshold active teaching methods categorized so the instructor can efficiently access and target the deployment of conceptually based lessons. The categories include teaching strategies for lecture on large and small class sizes; student action individually, in pairs, and groups; games; interaction through homework; student questions; role play; student presentations; and brainstorming. Along with a label for each method, we provide a brief summary of meaning, how to implement, and, for many, possible ways to implement in a mathematics course. Many of the methods are an adaptation of the active teaching methods available in books [1-3].

Smith, M.K., Trujillo, C., Su, T.T., 2011. The benefits of using clickers in small-enrollment seminar-style biology courses. *Life Sciences Education*. Vol. 10, 14-17.

Although the use of clickers and peer discussion is becoming common in large-lecture undergraduate biology courses, their use is limited in small-enrollment seminar-style courses. To investigate whether facilitating peer discussion with clickers would add value to a small-enrollment seminar-style course, we evaluated their usefulness in an 11-student Embryology course at the University of Colorado, Boulder. Student performance data, observations of peer discussion, and interviews with students revealed that adding clickers to a small-enrollment course 1) increases the chance students will do the required reading before class, 2) helps the instructor engage all students in the class, and 3) gives students a focused opportunity to share thinking and to learn from their peers.

Smith, M.K., Wood, W.B., Krauter, K., Knight, J.K., 2011. Combining peer discussion with instructor explanation increases student learning from in-class concept questions. *Life Science Education*. Vol. 10, 55-63.

Use of in-class concept questions with clickers can transform an instructor-centered “transmissionist” environment to a more learner-centered constructivist classroom. To compare the effectiveness of three different approaches using clickers, pairs of similar questions were used to monitor student understanding in majors’ and nonmajors’ genetics courses. After answering the first question individually, students participated in peer discussion only, listened to an instructor explanation only, or engaged in peer discussion followed by instructor explanation, before answering a second question individually. Our results show that the combination of peer discussion followed by instructor explanation improved average student performance substantially when compared with either alone. When gains in learning were analyzed for three ability groups of students (weak, medium, and strong, based on overall clicker performance), all groups benefited most from the combination approach, suggesting that peer discussion and instructor explanation are synergistic in helping students. However, this analysis also revealed that, for the nonmajors, the gains of weak performers using the combination approach were only slightly better than their gains using instructor explanation alone. In contrast, the strong performers in both courses were not helped by the instructor-only approach, emphasizing the importance of peer discussion, even among top-performing students.

Desaulniers Miller, M.C., Montplaisir, L.M., Offerdahl, E.G., Cheng, F.C., Ketterling, G.L. 2010. Comparison of views of the nature of science between natural science and nonscience majors. *Life Sciences Education*. Vol. 9, 45-54.

Science educators have the common goal of helping students develop scientific literacy, including understanding of the nature of science (NOS). University faculties are challenged with the need to develop informed NOS views in several major student subpopulations, including science majors and nonscience majors. Research into NOS views of undergraduates, particularly science majors, has been limited. In this study, NOS views of undergraduates in introductory environmental science and upper-level animal behavior courses were measured using Likert items and open-ended prompts. Analysis revealed similarities in students’ views between the two courses; both populations held a mix of naïve, transitional, and moderately informed views. Comparison of pre- and postcourse mean scores revealed significant changes in NOS views only in select aspects of NOS. Student scores on sections addressing six aspects of NOS were significantly different in most cases, showing notably uninformed views of the distinctions between scientific theories and laws. Evidence-based insight into student NOS views can aid in reforming undergraduate science courses and will add to faculty and researcher understanding of the impressions of science held by undergraduates, helping educators improve scientific literacy in future scientists and diverse college graduates.

Talanquer, V., Pollard, J. 2010. Let’s teach how we think instead of what we know. *Chem Educ Res. Pract.* Vol. 11, 74-83.

Despite multiple calls for reform, the curriculum for first-year college chemistry at many universities across the world is still mostly fact-based and encyclopedic, built upon a collection of isolated topics, oriented too much towards the perceived needs of chemistry majors, focused too much on abstract concepts and algorithmic problem solving, and detached from the practices, ways of thinking, and applications of both chemistry research and chemistry education research in the 21st century. This paper describes an alternative way of conceptualizing the introductory chemistry curriculum for science and engineering majors by

shifting the focus from learning chemistry as a body of knowledge to understanding *chemistry as a way of thinking*. Starting in 2007, we have worked on the development and implementation of a new curriculum intended to: promote deeper conceptual understanding of a minimum core of fundamental ideas instead of superficial coverage of multiple topics; connect core ideas between the course units by following well-defined learning progressions; introduce students to modern ways of thinking and problem-solving in chemistry; and involve students in realistic decision-making and problem-solving activities.

Glynn, S.M., Taasoobshirzai, G., Brickman, P. 2009. Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching*. Vol. 46, 127-146.

This study examined how 770 nonscience majors, enrolled in a core-curriculum science course, conceptualized their motivation to learn science. The students responded to the Science Motivation Questionnaire, a 30-item Likert-type instrument designed to provide science education researchers and science instructors with information about students' motivation to learn science. The students' scores on the Science Motivation Questionnaire were reliable and related to students' high school preparation in science, GPA in college science courses, and belief in the relevance of science to their careers. An exploratory factor analysis provided evidence of construct validity, revealing that the students conceptualized their motivation to learn science in terms of five dimensions: intrinsic motivation and personal relevance, self-efficacy and assessment anxiety, self-determination, career motivation, and grade motivation. Women and men had different profiles on these dimensions, but equivalent overall motivation to learn science. Essays by all of the students explaining their motivation to learn science and interviews with a sample of the students were used to interpret Science Motivation Questionnaire scores. The findings were viewed in terms of a social-cognitive theory of learning, and directions for future research were discussed.

Mayer, R.E., Stull, S., Deleeuw, K., Almeroth, K., Bimber, B., Chun, D., Bulger, M., Campbell, J., Knight, A., Zhang, H. 2009. Clickers in college classrooms: Fostering learning with questioning methods in large lecture classes. *Contemporary Educational Psychology*. Vol. 34, 51-57

What can be done to promote student–instructor interaction in a large lecture class? One approach is to use a personal response system (or “clickers”) in which students press a button on a hand-held remote control device corresponding to their answer to a multiple choice question projected on a screen, then see the class distribution of answers on a screen, and discuss the thinking that leads to the correct answer. Students scored significantly higher on the course exams in a college-level educational psychology class when they used clickers to answer 2 to 4 questions per lecture (clicker group), as compared to an identical class with in-class questions presented without clickers (no-clicker group, $d = 0.38$) or with no in-class questions (control group, $d = 0.40$). The clicker treatment produced a gain of approximately 1/3 of a grade point over the no-clicker and control groups, which did not differ significantly from each other. Results are consistent with the generative theory of learning, which predicts students in the clicker group are more cognitively engaged during learning

Salemi, M.K. 2009. Clickenomics: Using a classroom response system to increase student engagement in a large-enrollment principles of economics course. *Journal of Economic Education*. Fall 385-406.

One of the most important challenges facing college instructors of economics is helping students engage. Engagement is particularly important in a large-enrollment Principles of Economics course, where it can help students achieve a long-lived understanding of how economists use basic economic ideas to look at the world. The author reports how instructors can use Classroom Response Systems (clickers) to promote engagement in the Principles course. He draws heavily on his own experience in teaching a one semester Principles course at the University of North Carolina at Chapel Hill but also reports on how others have used clickers to promote engagement. He concludes with evidence that students find clickers very beneficial and with an assessment of the costs and benefits of adopting a clicker system.

Turpen, C., Finkelstein, N.D. 2009. Not all interactive engagement is the same: Variations in physics professors' implementation of peer instruction. *Physical Education Research*. Vol. 5, 020101

While educational reforms in introductory physics are becoming more widespread, how these reforms are implemented is less well understood. This paper examines the variation in faculty practices surrounding the implementation of educational reform in introductory physics courses. Through observations of classroom practice, we find that professors' actual practices differ strikingly. We present a framework for describing and capturing instructional choices and resulting variations in enacted practices for faculty who are implementing *Peer Instruction*. Based on our observations, there are a variety of scientific practices that are supported and modeled in the use of Peer Instruction. In all of the classrooms studied, students were found trying out and applying new physical concepts and discussing physics with their peers. However, there were large discrepancies in students' opportunities to engage in formulating and asking questions, evaluating the correctness and completeness of problem solutions, interacting with physicists, identifying themselves as sources of solutions, explanations, or answers, and communicating scientific ideas in a public arena. Case studies of six professors demonstrate how these variations in classroom practices, in aggregate, create different classroom norms, such as the relative emphasis on student sense-making vs answer-making during *Peer Instruction*.

Armstrong, N.A., Wallace, C.S., Chang, S.M. 2008. Learning from writing in college biology. *Res Sci Educ*. Vol. 38, 483-499.

This study used both quantitative and qualitative analyses to examine the influence of written arguments on learning in a college level introductory biology class and the types of metacognition employed by students while writing. Comparison of a treatment and control group indicates that the writing assignments used had minimal impact on overall content learning as measured by conventional exams. Subsequent interviews and think-aloud protocols with a subset of students indicated that writing arguments had the potential to foster learning through forward and backward search strategies. However, few of the students took advantage of this opportunity to use metacognitive skills. This study suggests that preparing written arguments is not sufficient, by itself, to have a reliable effect on student learning and is consistent with the view that students must be explicitly taught when and how to use different metacognitive strategies.

Crossgrove, K., Curran, K. 2008. Using clickers in nonmajor- and major-level biology courses: Student opinion, learning, and long-term retention of course material. *Life Sciences Education*. Vol. 7, 146-154.

Student response systems (clickers) are viewed positively by students and instructors in numerous studies. Evidence that clickers enhance student learning is more variable. After becoming comfortable with the technology during fall 2005–spring 2006, we compared student opinion and student achievement in two different courses taught with clickers in fall 2006. One course was an introductory biology class for nonmajors, and the other course was a 200 level genetics class for biology majors. Students in both courses had positive opinions of the clickers, although we observed some interesting differences between the two groups of students. Student performance was significantly higher on exam questions covering material taught with clickers, although the differences were more dramatic for the nonmajors biology course than the genetics course. We also compared retention of information 4 mo. after the course ended, and we saw increased retention of material taught with clickers for the nonmajors course, but not for the genetics course. We discuss the implications of our results in light of differences in how the two courses were taught and differences between science majors and nonmajors.

Dancy, M.H., Henderson, C. 2008. Barriers and promises in STEM reform. National Academies. http://www7.nationalacademies.org/bose/Dancy_Henderson_CommissionedPaper.pdf

It is not enough to simply conduct research and develop high quality teaching materials. High quality research and curriculum development is only valuable if it is actually used. We have been involved in several projects aimed at better understanding why research-based reform has not had as much impact as might be expected given the expenditures of time and money. In the paper that follows, we detail some of our findings and offer recommendations based on these findings. The paper is organized around two large barriers to reform. Barrier 1: STEM change strategies are primarily based on a development and dissemination change model. Barrier 2: There is little research effort devoted to the study and improvement of STEM change strategies or models

Gunersel, A.B., Simpson, N.J., Aufderheide, K.J., Wang, L. 2008. Effectiveness of calibrated peer review for improving writing and critical thinking skills in biology undergraduate students. *J of the scholarship of Teaching and Learning*, Vol. 8, 25-37.

This study focuses on student development with Calibrated Peer Review (CPR)™, a web-based tool created to promote writing and critical thinking skills. Research questions focus on whether or not students showed improvement in writing and reviewing competency with repeated use of CPR in a senior-level biology course and whether the difference between higher performing and lower performing students decreased over time. Four repeated measures analyses were conducted with different sets of students. Repeated measures analyses indicate that students showed improvement in writing skills and reviewer competency with repeated use of CPR. The difference between higher and lower performing students decreased over time in both writing skills and reviewer competency.

McConnell, D. 2008. Less talk, more action: Active learning in introductory geoscience courses. McConnell NAS White Paper, October.

Review of research-supported practices in large, general-education Earth Science classes. Practices focused on conceptual understanding and included a variety of practices from simple multiple choice questions to physical modeling. Analyses of data show that these methods were

preferred by students. These processes also improved student retention and increased logical thinking skills (McConnell, 2008).

Morse, D., Jutras, F. 2008. Implementing concept-based learning in a large undergraduate classroom. *Life Sciences Education*. Vol 7, 243-253.

An experiment explicitly introducing learning strategies to a large, first-year undergraduate cell biology course was undertaken to see whether awareness and use of strategies had a measurable impact on student performance. The construction of concept maps was selected as the strategy to be introduced because of an inherent coherence with a course structured by concepts. Data were collected over three different semesters of an introductory cell biology course, all teaching similar course material with the same professor and all evaluated using similar examinations. The first group, used as a control, did not construct concept maps, the second group constructed individual concept maps, and the third group first constructed individual maps then validated their maps in small teams to provide peer feedback about the individual maps. Assessment of the experiment involved student performance on the final exam, anonymous polls of student perceptions, failure rate, and retention of information at the start of the following year. The main conclusion drawn is that concept maps without feedback have no significant effect on student performance, whereas concept maps with feedback produced a measurable increase in student problem-solving performance and a decrease in failure rates.

Pundak, D., Rozner, S. 2008. Empowering engineering college staff to adopt active learning methods. *J. of Science Education and Technology*. Vol. 17, 1-12.

There is a growing consensus that traditional instruction in basic science courses, in institutions of higher learning, do not lead to the desired results. Most of the students who complete these courses do not gain deep knowledge about the basic concepts and develop a negative approach to the sciences. In order to deal with this problem, a variety of methods have been proposed and implemented, during the last decade, which focus on the “active learning” of the participating students. We found that the methods developed in MIT and NCSU were fruitful and we adopted their approach. Despite research-based evidence of the success of these methods, they are often met by the resistance of the academic staff. This article describes how one institution of higher learning organized itself to introduce significant changes into its introductory science courses, as well as the stages teachers undergo, as they adopt innovative teaching methods. In the article, we adopt the Rogers model of the innovative-decision process, which we used to evaluate the degree of innovation adoption by seven members of the academic staff. An analysis of interview and observation data showed that four factors were identified which influence the degree innovation adoption: (1) teacher readiness to seriously learn the theoretical background of “active learning”; (2) the development of an appropriate local model, customized to the beliefs of the academic staff; (3) teacher expertise in information technologies, and (4) the teachers_ design of creative solutions to problems that arose during their teaching.

Twigg, C.A. 2008. Math Lectures: An Oxymoron? The National Center for Academic Transformation. <http://www.center.rpi.edu/PlanRes/Math%20Lectures%20Editorial.htm>. 1-4.

One of the most enjoyable parts of our work at the National Center for Academic Transformation is that we learn new things all the time. There’s nothing like spending most of

your time engaging institutions of higher education in changing the way they think about teaching and learning to produce new ways of thinking. Based on eight years of experience in working with a large number of colleges and universities as they seek to improve student learning while reducing instructional costs, we have identified a number of “models” and “principles” to guide the redesign of large-enrollment courses. We have learned that each of our **Five Models for Course Redesign** can produce improved student learning and reduced instructional costs if it embodies our **Five Principles of Successful Course Redesign**. Therefore, as part of the application process to both our national and state redesign programs, we have heretofore asked teams to select a redesign model and explain how they will embody the Five Principles within it as the first step in the planning process.

Woelk, K. 2008. Optimizing the use of personal response devices (clickers) in large-enrollment introductory courses. *Journal of Chemical Education*. Vol. 85, 1400-1406.

While many studies are still in progress, especially those seeking to quantify learning outcomes, clicker systems have already been permanently installed in numerous college and university classrooms, particularly for use in large-enrollment first- and second-year science courses. Evidently, instructors are encouraged by their own or their colleagues’ evaluation of the technology so that they are willing to try or stick with this new way of interacting with students in the classroom. As the devices, hardware, and software have become less expensive, high school instructors are also experimenting with clickers.³ Teaching research studies (2, 3) and personal anecdotes, many of which are presented on Web pages, praise the successful contribution of clickers for enhancing the students’ engagement in large-enrollment courses (4) and the positive impact clickers may have on final course grades (5). A closer look at these studies indicates that the use of clickers particularly helps students with low grades to maintain or regain their interest in the subject matter. A recent literature review article is available (6) focusing on reports of clickers in educational settings.

Armstrong, N., Chang, S.M., Brickman, M. 2007. Cooperative learning in industrial-sized biology classes. *Life Sciences Education*. Vol. 6, 169-171.

This study examined the impact of cooperative learning activities on student achievement and attitudes in large-enrollment (~250) introductory biology classes. We found that students taught using a cooperative learning approach showed greater improvement in their knowledge of course material compared with students taught using a traditional lecture format. In addition, students viewed cooperative learning activities highly favorably. These findings suggest that encouraging students to work in small groups and improving feedback between the instructor and the students can help to improve student outcomes even in very large classes. These results should be viewed cautiously, however, until this experiment can be replicated with additional faculty. Strategies for potentially improving the impact of cooperative learning on student achievement in large courses are discussed.

Caldwell, J.E. 2007. Clickers in the large classroom: Current research and best-practice tips. *Life Science Education*. Vol. 6, 9-21.

Audience response systems (ARS) or clickers, as they are commonly called, offer a management tool for engaging students in the large classroom. Basic elements of the technology are discussed. These systems have been used in a variety of fields and at all levels of education.

Typical goals of RS questions are discussed, as well as methods of compensating for the reduction in lecture time that typically results from their use. Examples of ARS use occur throughout the literature and often detail positive attitudes from both students and instructors, although exceptions do exist. When used in classes, ARS clickers typically have either a benign or positive effect on student performance on exams, depending on the method and extent of their use, and create a more positive and active atmosphere in the large classroom. These systems are especially valuable as a means of introducing and monitoring peer learning methods in the large lecture classroom. So that the reader may use clickers effectively in his or her own classroom, a set of guidelines for writing good questions and a list of best-practice tips have been culled from the literature and experienced users.

Colbert, J.T., Olson, J.K., Clough, M.P. 2007. Using the web to encourage student-generated questions in large-format introductory biology classes. *Life Sciences Education*. Vol. 6, 42-48.

Students rarely ask questions related to course content in large-format introductory classes. The use of a Web-based forum devoted to student-generated questions was explored in a second semester introductory biology course. Approximately 80% of the enrolled students asked at least one question about course content during each of three semesters during which this approach was implemented. About 95% of the students who posted questions reported reading the instructor's response to their questions. Although doing so did not contribute to their grade in the course, approximately 75% of the students reported reading questions posted by other students in the class. Approximately 60% of the students reported that the Web-based question asking activity contributed to their learning of biology.

Henderson, C., Dancy, M.H. 2007. Barriers to the use of research-based instructional strategies: The dual role of individual and situational characteristics. *Physics Education Research*. Vol. 3, 020102.

Many proven research-based instructional strategies have been developed for introductory college-level physics. Significant efforts to disseminate these strategies have focused on convincing individual instructors to give up their traditional practices in favor of particular research-based practices. Yet, evidence suggests that the findings of educational research are, at best, only marginally incorporated into introductory physics courses. In this paper we present partial results of an interview study designed to generate new ideas about why proven strategies are so slow to integrate in mainstream instruction. Specifically we describe the results of openended interviews with five physics instructors who represent likely users of educational research. We found that these instructors have beliefs about teaching and learning that are more compatible with educational research than their self-described instructional practices. Instructors often blamed this discrepancy on situational factors that favored traditional instruction. A theoretical model is introduced to explain these findings.

Preszler, R.W., Dawe, A., Shuster, C.B., Shuster, M. 2007. Assessment of the effects of student response systems on student learning and attitudes over a broad range of biology courses. *Life Science Education*. Vol. 6, 29-41.

With the advent of wireless technology, new tools are available that are intended to enhance students' learning and attitudes. To assess the effectiveness of wireless student response systems in the biology curriculum at New Mexico State University, a combined study of student attitudes and performance was undertaken. A survey of students in six biology courses showed

that strong majorities of students had favorable overall impressions of the use of student response systems and also thought that the technology improved their interest in the course, attendance, and understanding of course content. Students in lower-division courses had more strongly positive overall impressions than did students in upper-division courses. To assess the effects of the response systems on student learning, the number of in-class questions was varied within each course throughout the semester. Students' performance was compared on exam questions derived from lectures with low, medium, or high numbers of in-class questions. Increased use of the response systems in lecture had a positive influence on students' performance on exam questions across all six biology courses. Students not only have favorable opinions about the use of student response systems, increased use of these systems increases student learning.

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.

Winter, D. 2007. Infusing mathematics with culture: Teaching technical subjects for social justice. *New Directions for Teaching and Learning*. Fall. 97-108.

For more than twenty years the undergraduate mathematics teaching community has conducted a deep conversation concerning the pedagogies appropriate for introductory mathematics courses, including college algebra, precalculus, and calculus (Ganter, 2000, 2001). Fueling this ongoing discussion has been the recognition that students' failure to "acquire a deep understanding of the material they are supposed to learn in their [mathematics] courses" (Graesser, Person, and Hu, 2002, p. 33) is still unacceptably common (Bookman and Friedman, 1994; Selden, Mason, and Selden, 1989; Smith, 1998).

This conversation has produced changes in the pedagogy of many mathematics courses (Hurley, Koehn, and Ganter, 1999; Lutzer, Maxwell, and Rodi, 2002), including increased use of cooperative learning and technology to promote learning. Recognizing the value of student interest as a resource for learning (Schiefele and Csikszentmihalyi, 1995), many instructors have highlighted the applicability and usefulness of mathematical techniques for solving problems in

the world outside the classroom (see Alper, Fendel, Fraser, and Resek, 1996; De Bock and others, 2003; Forman and Steen, 2000; Pollack, 1978; Walkerdine, 1988). One rationale for integrating social and cultural learning with traditional STEM learning is to use undergraduates' enthusiasm for social and political issues (National Survey of Student Engagement, 2004) as an engine to drive more abstract and conceptual mathematical learning (Carter and Brickhouse, 1989; Nix, Ryan, Manly, and Deci, 1999; Zoller, 1990).

Bunce, D.M., VandenPlas, J.R., Havanki, K.L. 2006. Comparing the effectiveness on student achievement of a student response system versus online WebCT quizzes. *Journal of Chemical Education*. Vol. 83, 488-494.

The use of computers to gather student responses is not new to science education. Use of electronic response systems, especially in large lectures, dates back to the 1960s (3). Research on the effectiveness of this approach has been limited to its influence on increased rates of passing the course (4). More work is needed to test the effectiveness of computers and ConcepTests on student achievement. It is this question that led to the incorporation of the Student Response System (SRS) into a second-semester nursing course. SRS is a Webbased questioning system (5) designed to assist instructors in receiving and analyzing student responses to questions posed in lecture or recitation. In this study, the electronic student response system, SRS, was used primarily as a means of delivering electronic ConcepTests for students working in pairs.

El-Rady, J. 2006. To click or not to click: That is the question. *Innovate, Journal of Online Education*. Vol. 2, 18.

It is not unusual in higher education these days to have classes with large enrollment. Indeed at the University of South Florida ([USF](#)) (enrollment 41,000), large classes are the norm. In the eight years during which I have been an instructor in the [Biology Department](#) at USF, my mid-level and lower-level classes have had enrollments ranging from 100-300 students. This large class size generates a few problems, especially in terms of engaging students in active learning. While a well-designed traditional lecture can be very effective, students can engage more directly with the material when they actively take part in their learning instead of simply passively receiving information. Another problem in large enrollment courses is low attendance, especially by students taking a non-major course.

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.

Allen, D., Tanner, K. 2005. Infusing active learning into the large-enrollment biology class: Seven strategies, from the simple to the complex. *Cell Biology Education*. Vol. 4, 262-268.

Science educators are urged (National Research Council [NRC], 1997, 2003; National Science Foundation, 1996) to adopt active-learning strategies and other alternatives to uninterrupted lecture to model the methods and mindsets at the heart of scientific inquiry, and to provide opportunities for students to connect abstract ideas to their real-world applications and acquire useful skills, and in doing so gain knowledge that persists beyond the course experience in which it was acquired. While these and other calls for reform dangle the carrot of promised cognitive gains before us (Bransford et al., 1999), the process of translating their message into the realities of practice in given classroom contexts remains a challenge of considerable magnitude. Perhaps because the inquiry-oriented methods that offer the most promise (Edgerton, 2001; Smith, K.A., et al., 2005) were often developed in small-class settings, the gap between promise and practice can seem almost impossible to close in the large-enrollment class environment that still predominates in the introductory course offerings of many colleges and universities. The conditions that led to creation of the large-enrollment class, particularly in research universities, are still with us (Edgerton, 2001) and are not likely to change in the foreseeable future. Thus, although the environment of a large class is not an easy one in which to thrive—either for the instructors who teach them (Carbone and Greenberg, 1998) or for the students who take them (Seymour and Hewitt, 1997; Tobias, 1990)—it is most probably here to stay

McConnell, D.A., Steer, D.N., Owens, K.D., Knight, C.C. 2005. How students think: Implications for learning in introductory geoscience courses. *Journal of Geoscience Education*. Vol. 53, 462-470.

Non-major students in introductory geoscience classes exhibit a wide range of intellectual development. Approximately half of these students do not have the skills to understand the abstract scientific concepts traditionally discussed in introductory classes. Many geological concepts will remain unlearned without appropriate activities that build on a foundation of concrete examples. The good news is that these same students can improve their logical thinking skills when they participate in challenging in-class collaborative learning exercises with their more intellectually sophisticated peers. While the exercises themselves are important in promoting the development of higher-order thinking skills, the group interaction also appears to be a significant contributor to the improvement of reasoning.

Zusho, A., Pintrich, P.R. 2003. Skill and will: The role of motivation and cognition in the learning of college chemistry. *Int. Jour. Science Education*. Vol. 25, 1081-1094.

This study investigated how students' level of motivation and use of specific cognitive and self-regulatory strategies changed over time, and how these motivational and cognitive components in turn predicted students' course performance in chemistry. Participants were 458 students

enrolled in introductory college chemistry classes. Participants' motivation and strategy use were assessed at three time points over the course of one semester using self-report instruments. Results showed an overall decline in students' motivational levels over time. There was also a decline in students' use of rehearsal and elaboration strategies over time; students' use of organizational and self-regulatory strategies increased over time. These trends, however, were found to vary by students' achievement levels. In terms of the relations of motivation and cognition to achievement, the motivational components of self-efficacy and task value were found to be the best predictors of final course performance even after controlling for prior achievement.

Brickhouse, N.W., Dagher, Z.R., Letts, W.J., Shipman, H.L. 2000. Diversity of students' views about evidence, theory, and the interface between science and religion in an astronomy course. *Journal of Research in Science Teaching*. Vol. 37, 340-362.

Arguments for teaching about the nature of science have been made for several decades. The most recent science education policy documents continue to assert the need for students to understand the nature of science. However, little research actually explores how students develop these understandings in the context of a specific course. We examine the growth in students' understanding about the nature of astronomy in a one-semester college course. In addition to student work collected for 340 students in the course, we also interviewed focus students three times during the course. In this article we briefly describe class data and discuss in detail how five students developed their ideas throughout the course. In particular, we show the ways in which students respond to instruction with respect to the extent to which they (a) demand and examine evidence used for justifying claims, (b) integrate scientific and religious views, and (c) distinguish between scientific and nonscientific theories.

Hall, S.R., Waitz, I., Brodeur, D.R., Soderholm, D.H., Nsr, R. 2002. Adoption of active learning in a lecture-based engineering class. 32nd ASEE/IEEE Frontiers in Education Conference. November, Boston MA.

Three years ago, the Department of Aeronautics and Astronautics at MIT expanded its repertoire of active learning strategies and assessment tools with the introduction of muddiest-point-in-the-lecture cards, electronic response systems, concept tests, peer coaching, course web pages, and web-based course evaluations. This paper focuses on the change process of integrating these active learning strategies into a traditional lecture-based multidisciplinary course, called Unified Engineering. The description of the evolution of active learning in Unified Engineering is intended to underscore the motivation and incentives required for bringing about the change, and the support needed for sustaining and disseminating active learning approaches among the instructors.

Robertson, L.J. 2000. Twelve tips for using a computerized interactive audience response system. *Medical Teacher*. Vol. 22, 237-240.

The role of the lecture in medical education has recently been called into question. Adults learn more effectively through active learning therefore where is the place for the traditional lecture? This paper describes the use of a computerized audience response system to transform large group teaching sessions into active learning experiences, thereby securing a future for the lecture format. We pass on our tips, gleaned from our varied experiences using the system, for the successful design and running of such interactive sessions.

Wright, J.C., Millar, S.B., Kosciuk, S.A., Penberthy, D.L., Williams, P.H., Wampold, B.E. 1998. A novel strategy for assessing the effects of curriculum reform on student competence. *Journal of Chemical Education*. Vol. 75. 986-993.

In this paper, we describe a new assessment strategy that was designed to determine whether such changes in student skills are observable by independent and unbiased observers. The methods were developed by representatives of the University of Wisconsin Chemistry faculty to assess reform success in ways that they would believe. The strategy is applicable to course comparisons that are often found in curriculum reform projects where the project design does not allow the controlled course settings that are sought for educational research. Two sections of a large analytical chemistry course for first-year undergraduates were assessed. One section was taught using methods that focused on lectures that carefully led the student to mastery of the course material using methods that encouraged student questions and participation. The other section was taught using cooperative learning methods that emphasized group work and self-discovery (12). These sections are labeled responsive lecturing (RL) and structured active learning (SAL). The SAL approach had been developed in 1992 and refined during the subsequent spring semesters. Unbiased external evaluation judged that both sections represented best practice for each method.

Ebert-May, D., Brewer, C., Allred, S. 1997. Innovation in large lectures: Teaching for active learning. *BioScience*, Vol. 47, 601-607.

Although the two cases we describe use different strategies for changing instruction, they are based on the same goal-teaching to involve active learning by all students. The NAU case describes an experiment that tested the relative effectiveness of inquiry-based instruction. The UM case illustrates how such teaching strategies can be easily incorporated into the largest lecture courses.

Groccia, J.E., Miller, J.E. 1996. Collegiality in the classroom: the use of peer learning assistants in cooperative learning in introductory biology. *Innovative Higher Education*. Vol. 21, 87-100.

Experienced undergraduate students served as Peer Learning Assistants (PLAs) to facilitate group process and dynamics in cooperative learning groups. The use of this model in large classes (150 students) resulted in statistically significant improvements in group performance and satisfaction with the group experience. PLAs defused conflict in groups which were, by their cognitively diverse nature, conflict-prone. Student attitudes about their PLAs and PLA attitudes about the experience were positive. Faculty productivity was substantially enhanced because group dynamics problems rarely landed in the faculty office.

Trigwell, K., Prosser, M., Taylor, P. 1994. Qualitative differences in approaches to teaching first year university science. *Higher Education*. Vol. 27, 75-84.

Abstract. Changing lecturers' teaching strategies to improve learning in higher education may mean first having to address the intentions associated with those strategies. The study reported in this paper used a phenomenographic approach to explore the intentions associated with the teaching strategies of first year physical science lecturers. Approaches found ranged from those involving information transmission to those where the intention was to develop learning

through conceptual change, but in all approaches, logical relations were found between intention and strategy. The implications for attempts to improve teaching through developing strategies are discussed.