

STEM Topic: In-Class/Online discussion

Anderson, W.A., Banerjee, U., Drennan, C.L., Elgin, C.R., Epstein, L.R., Handelsman, J., Hatfull, G.F., Losick, R., O'Dowd, D.K., Olivers, B.M., Strobel, S.A., Walker, G.C., Warner, I.M. 2011. Changing the culture of science education at research universities. *Science*. Vol. 331, 152-154.

Professors have two primary charges: generate new knowledge and educate students. The reward systems at research universities heavily weight efforts of many professors toward research at the expense of teaching, particularly in disciplines supported extensively by extramural funding (1). Although education and lifelong learning skills are of utmost importance in our rapidly changing, technologically dependent world (2), teaching responsibilities in many STEM (science, technology, engineering, and math) disciplines have long had the derogatory label "teaching load" (3, 4). Some institutions even award professors "teaching release" as an acknowledgment of their research accomplishments and success at raising outside research funds.

Richards-Babb, M., Drelick, J., Henry, Z., Robertson-Honecker, J. 2011. Online homework, help or hindrance? What students think and how they perform. *Research and Teaching*. Vol. 40, 81-94.

To improve students' retention rates in general chemistry, online homework was introduced into our curriculum. Replacing quizzes directly by online homework significantly improved ($p < .0005$) success rates in second-term general chemistry. Attitudinal Likert survey results indicate that the majority of students completed the online homework assignments (90%) and viewed the assignments as worth the effort (83.5%). Students were overwhelming (85.7%) in their recommendation that online homework use should continue. More consistent study habits were reported by 75.6% of students, and students reported using a suite of effective problem-solving approaches for questions marked as incorrect. Our instructors have willingly embraced the use of online homework and point to the incredible amount of time savings for the instructor as reason enough to use online homework.

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.

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.

Banner, B.J. 2010. Motivating and assisting adult, online chemistry students: A review of the literature. *J. Sci Educ Technol*. Vol. 19, 215-236.

While comprehensive texts, articles, and literature reviews presenting research in the singular arenas of motivation, help-seeking, and online science learning are relatively easy to find, syntheses and interactions between these constructs are lacking. Part I of this review addresses this knowledge gap by drawing together key research from the domains of educational psychology and adult education, addressing the constructs of motivation, self-efficacy, adult learning, and help-seeking. Part II of this review extends and applies the motivation and help-seeking discussion to the emerging and exciting field of online chemistry education. The result is a comprehensive synthesis of the strengths and limitations of the currently existing body of knowledge related to the motivation and help-seeking behaviors of adult, online chemistry students.

Perez, K.E., Strauss, E.A., Downey, N., Galbraith, A., Jeanne, R., Cooper, S. 2010. Does displaying the class results affect student discussion during peer instruction? *Life Sciences Education*. Vol. 9, 133-140.

The use of personal response systems, or clickers, is increasingly common in college classrooms. Although clickers can increase student engagement and discussion, their benefits also can be overstated. A common practice is to ask the class a question, display the responses, allow the students to discuss the question, and then collect the responses a second time. In an introductory biology course, we asked whether showing students the class responses to a question biased their second response. Some sections of the course displayed a bar graph of the student responses and others served as a control group in which discussion occurred without seeing the most common answer chosen by the class. If students saw the bar graph, they were 30% more likely to switch from a less common to the most common response. This trend was more pronounced in true/false questions (38%) than multiple-choice questions (28%). These results suggest that observing the most common response can bias a student's second vote on a question and may be misinterpreted as an increase in performance due to student discussion alone.

Smith, M.K., Wood, W.B., Adams, W.K., Wieman, C., Knight, J.K., Guild, N., Su, T.T. 2009. Why peer discussion improves student performance on in-class concept questions. *Science*. Vol. 323, 122-125.

When students answer an in-class conceptual question individually using clickers, discuss it with their neighbors, and then revote on the same question, the percentage of correct answers typically increases. This outcome could result from gains in understanding during discussion, or simply from peer influence of knowledgeable students on their neighbors. To distinguish between these alternatives in an undergraduate genetics course, we followed the above exercise with a second, similar (isomorphic) question on the same concept that students answered individually. Our results indicate that peer discussion enhances understanding, even when none of the students in a discussion group originally knows the correct answer.

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.

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.

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.

Guertin, L.A., Zappe, S.E., Kim, H. 2007. Just-in-Time teaching exercises to engage students in an introductory-level dinosaur course. *J Sci Educ Technol*. Vol. 16, 507-514.

The Just-in-Time Teaching (JiTT) technique allows students to be engaged in course material outside of the classroom by answering web-based questions. The responses are summarized and presented to students in class with a follow-up active learning exercise. College students enrolled in an introductory-level general education geoscience course were surveyed over a two-semester period on their engagement level during lecture and perceived learning of course content. Data show that students are able to reflect on their prior knowledge and construct new knowledge with weekly graded JiTT exercises. Despite increasing and competing pressures outside of the classroom, students reported increased learning and engagement in a course with required weekly assignments.

McDaniel, C.N., Lister, B.C., Hanna, M.H., Roy, H. 2007. Increased learning observed in redesigned introductory biology course that employed web-enhanced, interactive pedagogy. *Life Sciences Education*. Vol. 6, 243-249.

Our Introduction to Biology course (BIOL 1010) changed in 2004 from a standard instructor centered, lecture-homework-exam format to a student-centered format that used Web-enhanced, interactive pedagogy. To measure and compare conceptual learning gains in the traditional course in fall 2003 with a section of the interactive course in fall 2004, we created concept inventories for both evolution and ecology. Both classes were taught by the same instructor who had taught BIOL 1010 since 1976, and each had a similar student composition with comparable biological knowledge. A significant increase in learning gain was observed with the Web enhanced, interactive pedagogy in evolution (traditional, 0.10; interactive, 0.19; $p = 0.024$) and ecology (traditional, 0.05; interactive, 0.14; $p = 0.000009$) when assessment was made unannounced and for no credit in the last week of classes. These results strengthen the case for augmenting or replacing instructor-centered teaching with Web-enhanced, interactive, student centered teaching. When assessment was made using the final exam in the interactive course, for credit and after studying, significantly greater learning gains were made in evolution (95%, 0.37, $p = 0.0001$) and ecology (143%, 0.34, $p = 0.000003$) when compared with learning gains measured without credit or study in the last week of classes.

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 Web based 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.

Carlson, P.A., Berry, F.C., Voltmer, D. 2005. Incorporating student peer-review into an introduction to engineering design course. 35th ASEE/IEEE Frontiers in Education Conference, October, Indianapolis, IN.

We report on a project to improve the teaching of engineering design at the junior level. Peer review of student work is an integral part of collaborative learning and reform-driven engineering education. Yet successfully implementing this pedagogical technique requires significant amounts of instructor and class time. Furthermore, if adequate formative assessment does not emerge from peer review, the experience may devolve into "busy work" in the eyes of the student. Here, we give early results from an NSF-funded study using Calibrated Peer Review (a web-delivered, collaborative learning environment) to enhance learning in engineering design.

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.

Bonhm, S., Beichner, R., Deardorff, D. 2001. Online homework: Does it make a difference? *The Physics Teacher*. Vol. 39, 293-297.

Readers may have heard of WebAssign, CAPA, OWL, or Homework Service, a few of the systems available to automate the process of collecting and grading student homework. Some of you may already be users of one of these systems, others may have wondered about using them, and still others might believe it is unconscionable to relegate something as important as homework to a machine. Computer homework systems can certainly be a time-saver to instructors (as least in large-enrollment courses), but whether the students are helped or harmed by the use of the system is another issue.

Crouch, C.H., Mazur, E. 2001. Peer instruction: Ten years of experience and results. *American Journal of Physics*. Vol. 69, 970-978.

We report data from ten years of teaching with Peer Instruction ~PI! in the calculus- and algebra-based introductory physics courses for nonmajors; our results indicate increased student mastery of both conceptual reasoning and quantitative problem solving upon implementing PI. We also discuss ways we have improved our implementation of PI since introducing it in 1991. Most notably, we have replaced in-class reading quizzes with pre-class written responses to the reading, introduced a research-based mechanics textbook for portions of the course, and incorporated cooperative learning into the discussion sections as well as the lectures. These improvements are intended to help students learn more from pre-class reading and to increase student engagement in the discussion sections, and are accompanied by further increases in student understanding.

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.

Musheno, B.V., Lawson, A.E. 1999. Effects of learning cycle and traditional text on comprehension 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).