

STEM Topic: Student Motivation and Attitudes

Maltese, A.V., Tai, R.H. 2011. Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. Wiley Periodicals, Inc. *Science Education*. 1-31.

As the global economic crisis continues, sustaining the United States' position as a leader in research and development is a top concern of policy makers. Looking to increase the number of students pursuing degrees in STEM (science, technology, engineering, and mathematics), calls for improved mathematics and science education abound. We completed a two-part analysis to assess the school-based factors related to students choosing to complete a major in STEM. The results indicate that the majority of students who concentrate in STEM make that choice during high school, and that choice is related to a growing interest in mathematics and science rather than enrollment or achievement. These results indicate that the current policy focus on advanced-level course taking and achievement as measures to increase the flow of students into STEM may be misguided.

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.

Milner-Bolotin, M., Antimirova, T., Petrov, A. 2010. Clickers beyond the first-year science classroom. *Journal of College Science Teaching*. Vol. 40, 14-19.

This case study's primary objective is to describe the implementation of the electronic response system (clickers) in a small (N = 25) second-year physics course at a large public university and to draw attention of the science faculty who teach upper-level science courses to the potential benefits of this pedagogy. This pilot study discusses the impact of the clicker-enhanced pedagogy on students' cognitive and affective outcomes and their attitudes toward using clickers. We also outline challenges faced by the students and the instructors on the way of successful clicker implementation beyond the first year and suggest a few possible ways of addressing them.

Armbruster, P., Patel, M., Johnson, E., Weiss, M. 2009. Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology. *Life Science Education*. Vol. 8, 203-213.

We describe the development and implementation of an instructional design that focused on bringing multiple forms of active learning and student-centered pedagogies to a one-semester, undergraduate introductory biology course for both majors and non-majors. Our course redesign consisted of three major elements: 1) reordering the presentation of the course content in an attempt to teach specific content within the context of broad conceptual themes, 2) incorporating active and problem-based learning into every lecture, and 3) adopting strategies to create a more student-centered learning environment. Assessment of our instructional design consisted of a student survey and comparison of final exam performance across 3 years – 1 year before our course redesign was implemented (2006) and during two successive years of implementation (2007 and 2008). The course restructuring led to significant improvement of self-reported student engagement and satisfaction and increased academic performance. We discuss the successes and ongoing challenges of our course restructuring and consider issues relevant to institutional change.

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.

Ortiz-Robinson, N.L., Ellington, A.J. 2009. Learner-centered strategies and advanced mathematics: A study of students' perspectives. *Primus*. Vol. 19, 463-472.

A number of learner-centered strategies were implemented during a two semester course in real analysis that is traditionally taught in lecture format. We seek to understand the role that these strategies can have in this proof-intensive theoretical mathematics classroom and the perceived benefits by the students. Although learner-centered strategies are a welcome addition in many applied mathematics courses and are known to be successful, the literature indicates that these remain largely absent from more advanced courses [9]. In an effort to correlate student resistance and acceptance of these strategies in different classroom settings we included an applied differential equations course in the study. Student feedback was obtained for two semesters of the real analysis course and compared to the feedback obtained during one semester of the differential equations course.

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.

MacArthur, J.R., Jones, L.L. 2008. A review of literature reports of clickers applicable to college chemistry classrooms. *Chemistry Education Research and Practice*. Vol. 9, 187-195.

The use of clickers (also referred to as Audience Paced Feedback, Classroom Communication Systems, Personal Response Systems, Electronic Voting Systems, Student Response Systems, Audience Response Systems, voting-machines, and zappers) has grown in college chemistry classrooms within the last decade. This review summarizes the pedagogic applications of research on clickers as well as insights from their practical use. Fifty-six publications reporting on the use of clickers in college-level science classrooms are categorized as practical application or research studies, and reviewed. Publications on the practical use of clickers suggest that students have a positive attitude towards the technology and that many benefits and few drawbacks are associated with its use. Research studies show that the use of clickers results in measurable increases in student learning in some cases and inconclusive results in other cases. In every published report of student improvement with the use of clickers, the course included student collaboration of some form.

Radosevich, D.J., Salomon, R., Radosevich, D.M., Kahn, P. 2008. Using student response systems to increase motivation, learning, and knowledge retention. <http://elearn.uaa.alaska.edu/Shared%20Documents/classroom%20Clickers/Articles%20on%20Clickers/UsingSRSMontclairStU.pdf>

Student response system (SRS) technology is one of the many tools available to help instructors create a rich and productive learning environment even within the framework of a traditional lecture-based lesson. The SRS presents questions to the class, prompts students to enter responses using a pocket-sized keypad transmitter (Figure 1), and provides aggregated feedback regarding student responses to the instructor. An SRS can be used to assess students' comprehension of complex material, affording both the instructor and the students immediate feedback so that instruction can be tailored to student needs. Furthermore, the question-and-feedback process has the potential to promote greater student engagement in class discussions, and group activities in which students solve problems together and submit answers using the SRS can promote active learning. The primary goal of this study is to examine the extent to which SRS can impact student motivation and foster active learning.

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. *Live 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.

Felder, R.M, Brent, R. 2007. Cooperative Learning. *Active Learning: Models from the Analytical Sciences*, ACS Symposium Series 970, Chapter 4. Washington, DC: American Chemical Society, 2007.

Cooperative learning is an approach to groupwork that minimizes the occurrence of those unpleasant situations and maximizes the learning and satisfaction that result from working on a high-performance team. A large and rapidly growing body of research confirms the effectiveness of cooperative learning in higher education (1-4). Relative to students taught traditionally—i.e., with instructor-centered lectures, individual assignments, and competitive grading—cooperatively taught students tend to exhibit higher academic achievement, greater persistence through graduation, better high-level reasoning and critical thinking skills, deeper understanding of learned material, greater time on task and less disruptive behavior in class, lower levels of anxiety and stress, greater intrinsic motivation to learn and achieve, greater ability to view situations from others' perspectives, more positive and supportive relationships with peers, more positive attitudes toward subject areas, and higher self-esteem. Another nontrivial benefit for instructors is that when assignments are done cooperatively, the number of papers to grade decreases by a factor of three or four.

Felder, R.M. 2007. Sermons for grumpy campers. *Chemical Engineer Education*. Vol. 41, 183-184.

When you use a proven teaching method that makes students uncomfortable, it's important to let them know why you're doing it. If you can convince them that it's not for your own selfish or lazy purposes but to try to improve their learning and grades, they tend to ramp down their resistance long enough to see the benefits for themselves. I've developed several mini-sermons to help with this process. If any look useful, feel free to appropriate them.

Felder, R.M. 2007. Reaching the second tier: Learning and teaching styles in college science education. <http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/Secondtier.html>

In her recent study of college science instruction, Sheila Tobias [19] defines two tiers of entering college students, the first consisting of those who go on to earn science degrees and the second those who have the initial intention and the ability to do so but instead switch to nonscientific fields. The number of students in the second category might in fact be enough to prevent the shortfall of American scientists and engineers that has been widely forecast for the coming decade.

Felder, R.M. 2006. Teaching engineering in the 21st century with a 12th century teaching model: How bright is that? *Chemical Engineering Education*. Vol. 40, 110-113.

If you took a stroll down a hall of the University of Bologna in the 12th Century and looked into random doorways, you would have seen professors holding forth in Latin to rooms full of bored-looking students. The professors would be droning on interminably in language few of the students could understand, perhaps occasionally asking questions, getting no responses, and providing the answers themselves. You might see a few students jotting down notes on recycled parchment, a few more sneaking occasional bites of the cold pizza slices concealed in their academic robes, some sleeping, and most just staring vacantly, inwardly cursing the fact that iPods would not become readily available for another 800 years. Toward the end of the lecture, one student would ask "Professore, siamo responsabili per tutta questa roba nell'esame?" and that would be the only active student involvement in the class. Eventually the class would be released, and the students would leave grumbling to each other about the 150 pages of reading assigned for the next period and expressing gratitude for the Cliffs Notes version of the text.

Oakley, B.A., Hanna, D.M., Kuzmyn, Z., Felder, R.M. 2007. Best practices involving teamwork in the classroom: Results from a survey of 6435 engineering student respondents. *IEEE Transactions on Education*. Vol. 50, 266-273.

A teamwork survey was conducted at Oakland University, Rochester, MI, in 533 engineering and computer science courses over a two-year period. Of the 6435 student respondents, 4349 (68%) reported working in teams. Relative to the students who only worked individually, the students who worked in teams were significantly more likely to agree that the course had achieved its stated learning objectives ($p < 0.001$). Regression analysis showed that roughly one-quarter of the variance in belief about whether the objectives were met could be explained by four factors: 1) student satisfaction with the team experience; 2) the presence of instructor guidance related to teamwork; 3) the presence of slackers on teams; and 4) team size. Pearson product-moment correlations revealed statistically significant associations between agreement that the course

objectives had been fulfilled and the use of student teams and between satisfaction with teams and the occurrence of instructor guidance on teamwork skills. These and other results suggest that assigning work to student teams can lead to learning benefits and student satisfaction, provided that the instructor pays attention to how the teams and the assignments are set up.

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.

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).

Felder, R.M., Brent, R. 2005. Understanding student differences. *Journal of Engineering Education*. January. 16.

Students have different levels of motivation, different attitudes about teaching and learning, and different responses to specific classroom environments and instructional practices. The more thoroughly instructors understand the differences, the better chance they have of meeting the diverse learning needs of all of their students. Three categories of diversity that have been shown to have important implications for teaching and learning are differences in students' learning styles (characteristic ways of taking in and processing information), approaches to learning (surface, deep and strategic), and intellectual development levels (attitudes about the nature of knowledge and how it should be acquired and evaluated). This article reviews models that have been developed for each of these categories, outlines their pedagogical implications, and suggest areas for further study.

Miller, J.D. 2004. Public understanding of, and attitudes toward, scientific research: what we know and what we need to know. Sage Publications, *Public Understanding Science*. Vol. 13, 273-294.

Over the last four decades, a substantial body of national survey material has been collected in the US concerning the public understanding of science and technology. Using this body of research, this analysis outlines the major trends from 1957 to 1999 and discusses their implications for public understanding of, and attitudes toward, scientific research. The analysis found that although the rate of civic scientific literacy in the US is only now approaching 20 percent, there is a strong and continuing public belief in the value of scientific research for economic prosperity and for the quality of life. Even though there are some continuing reservations about the pace of change engendered by science and technology and the relationship between science and faith, the public consistently reconciles these differing perceptions in favor of science.

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.

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.

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.