STEM Subject Physics

Wieman, C. (September 01, 2012). Applying New Research to Improve Science Education. Issues in Science & Technology, 29, 1.)

> Insights from several fields on how people learn to become experts can help us to dramatically enhance the effectiveness of science, technology, engineering, and mathematics education. Science, technology, engineering, and mathematics (STEM) education is critical to the U.S. future because of its relevance to the economy and the need for a citizenry able to make wise decisions on issues faced by modern society. Calls for improvement have become increasingly widespread and desperate, and there have been countless national, local, and private programs aimed at improving STEM education, but there continues to be little discernible change in either student achievement or student interest in STEM. Articles and letters in the spring and summer 2012 editions of Issues extensively discussed STEM education issues. Largely absent from these discussions, however, is attention to learning. This is unfortunate because there is an extensive body of recent research on how learning is accomplished, with clear implications for what constitutes effective STEM teaching and how that differs from typical current teaching at the K-12 and college levels. Failure to understand this learning- focused perspective is also a root cause of the failures of many reform efforts.

Miller, K., Lasry, N., Chu, K., & Mazur, E. (July 01, 2013). Role of Physics Lecture Demonstrations in Conceptual Learning. *Physical Review Special Topics - Physics Education Research*, *9*, 2, 20113.

> Previous research suggests that students' prior knowledge can interfere with how they observe and remember lecture demonstrations. We measured students' prior knowledge in introductory mechanics and electricity and magnetism at two large universities. Students were then asked to predict the outcome of lecture demonstrations. We compare students' predictions before having seen the demonstration to what they report having seen both right after the demonstration and several weeks later. We report four main findings. First, roughly one out of every five observations of a demonstration is inconsistent with the actual outcome. Second, students who understand the underlying concepts before observing the demonstration are more likely to observe it and remember it correctly. Third, students are roughly 20% (23%) more likely to observe a demonstration correctly if they predict the outcome first, regardless of whether the prediction is correct or not. Last, conceptual learning is contingent on the student making a correct observation. This study represents an initial step towards understanding the disconnect reported between demonstrations and student learning.

Hoskinson, A.-M., Caballero, M. D., & Knight, J. K. (2013). How Can We Improve Problem Solving in Undergraduate Biology? Applying Lessons from 30 Years of Physics Education Research. *CBE Life Sciences Education*, *12*(2), 153–161. doi:10.1187/cbe.12-09-0149.

> If students are to successfully grapple with authentic, complex biological problems as scientists and citizens, they need practice solving such problems during their undergraduate years. Physics

education researchers have investigated student problem solving for the past three decades. Although physics and biology problems differ in structure and content, the instructional purposes align closely: explaining patterns and processes in the natural world and making predictions about physical and biological systems. In this paper, we discuss how research-supported approaches developed by physics education researchers can be adopted by biologists to enhance student problem-solving skills. First, we compare the problems that biology students are typically asked to solve with authentic, complex problems. We then describe the development of research-validated physics curricula emphasizing process skills in problem solving. We show that solving authentic, complex biology problems requires many of the same skills that practicing physicists and biologists use in representing problems, seeking relationships, making predictions, and verifying or checking solutions. We assert that acquiring these skills can help biology students become competent problem solvers. Finally, we propose how biology scholars can apply lessons from physics education in their classrooms and inspire new studies in biology education research.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (May 12, 2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences.*

To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineer-ing, and mathematics (STEM) courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories in-creased by 0.47 SDs under active learning (n = 158 studies), and that the odds ratio for failing was 1.95 under traditional lecturing (n = 67 studies). These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Heterogeneity analyses indicated that both results hold across the STEM disciplines, that active learning increases scores on con-cept inventories more than on course examinations, and that ac-tive learning appears effective across all class sizes—although the greatest effects are in small (n ≤ 50) classes. Trim and fill analyses and fail-safe n calculations suggest that the results are not due to publication bias. The results also appear robust to variation in the methodological rigor of the included studies, based on the quality of controls over student quality and instructor identity. This is the largest and most comprehensive metaanalysis of undergraduate STEM education published to date. The results raise questions about the continued use of traditional lecturing as a control in research studies, and support active learning as the preferred, empirically validated teaching practice in regular classrooms.

Deslauriers, L., Schelew, E., Wieman, C. 2011. Improved learning in a large-enrollment physics class. Science. Vol. 332, 862-888.

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.

Formica, S.P., Easley, J.L., Spraker, M.C. 2010. Transforming common-sense beliefs into Newtonian thinking through Just-In-Time Teaching. Physical Review Special Topics, Physics Education Research, 6, 020106.

To determine whether teaching an introductory physics course with a traditional lecture style or with Just-in-Time teaching _a student-centered, interactive-engagement style_ will help students to better understand Newtonian concepts, such as Newton's Third Law, 222 students in introductory physics courses taught by traditional lecture styles and Just-in-Time teaching at North Georgia College & State University over the span of five semesters were examined using the Force Concept Inventory as a pretest and a post-test. Overall, the gains favor the Just-in-Time teaching method with a 37.6%_2.0% gain compared to the 17.9%_2.5% seen in traditional lecture classes. When analyzing only those gains pertaining to the Newton's Third Law questions, the results again favor the Just-in-Time teaching method with a gain of 50.8%_4.1% while the traditional lecture classes only saw a gain of 6.6%_5.2%. We also employed a new method of analysis which was a BIT Coding method created to quickly identify students' understanding of Newton's Third Law questions. This study shows that students in courses that are taught using the Just-in-Time teaching strategy better understand Newton's Third Law after instruction than do students in traditional lecture courses.

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.

Miyake, A., Kost-Smith, L.E., Finkelstein, N.D., Pollock, S.J., Cohen, G.L., Ito, T.A. 2010. Redcucing the gender achievement gap in college science: A classroom study of values affirmation. Science. Vol. 330, 1234-1238.

In many science, technology, engineering, and mathematics disciplines, women are outperformed by men in test scores, jeopardizing their success in science-oriented courses and careers. The current study tested the effectiveness of a psychological intervention, called values affirmation, in reducing the gender achievement gap in a college-level introductory physics

class. In this randomized double-blind study, 399 students either wrote about their most important values or not, twice at the beginning of the 15-week course. Values affirmation reduced the male-female performance and learning difference substantially and elevated women's modal grades from the C to B range. Benefits were strongest for women who tended to endorse the stereotype that men do better than women in physics. A brief psychological intervention may be a promising way to address the gender gap in science performance and learning.

Turpen, C., Finkelstein, N.D., 2010. The construction of different classroom norms during Peer Instruction: Students perceive differences. Physics Education Research 6. 020123.

> This paper summarizes variations in instructors' implementation practices during Peer Instruction _PI_ and shows how these differences in practices shape different norms of classroom interaction. We describe variations in classroom norms along three dimensions of classroom culture that are integral to Peer Instruction, emphasis on: _1_ faculty-student collaboration, _2_ student-student collaboration, and _3_ sense-making vs answer-making. Based on interpretations by an observing researcher, we place three different PI classrooms along a continuum representing a set of possible norms. We then check these interpretations against students' perceptions of these environments from surveys collected at the end of the term. We find significant correspondence between the researchers' interpretations and students' perceptions of Peer Instruction in these environments. We find that variation in faculty practices can set up what students perceive as discernibly different norms. For interested instructors, concrete classroom practices are described that appear to encourage or discourage these norms.

Chen, Z., Stelzer, T., Gladding, G. 2010. Using multimedia modules to better prepare students for introductory physics lecture. Physical Review Special Topics, Physics Education Research, 6 , 010108.

> It is known that introductory physics students rarely, if ever, read the textbook prior to coming to lecture. In this study, we report results from a curriculum intervention in a large enrollment introductory physics class that addresses this problem. In particular, we introduced web-based multimedia learning modules _MLMs_ as a "prelecture assignment" designed to better prepare students before coming to lecture. We used student performance on "preflight questions" that they answer prior to lecture as a measure of their before-lecture understanding of the physics concepts. We found significant improvement in student performance and on the vast majority of these preflight questions as compared to that from previous semesters in which MLMs were not available. We found significant improvement for all students, independent of their background or ability level.

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*.

Willoughby, S.D., Gustafson, E. 2009. Technology talks: clickers and grading incentive in the large lecture hall. American Journal of Physics. Vol. 77, 180-184.

Two sections of an introductory astronomy class were given different grading incentives for clicker participation for two consecutive semesters. In the high stakes classroom points were awarded only for correct answers, in contrast to the low stakes classroom in which points were awarded simply for participating. Self-formed groups of four students each were recorded in both sections several times during the spring 2007 semester and their conversations were transcribed and categorized into nine topics to analyze the variations between the sections. Performance on clicker questions and tendency to block vote were correlated with class grades and gains for the pre- and post-test scores on the Astronomy Diagnostic Test.

Henderson, C., Dancy, M.H. 2008. Physics faculty and educational researchers: Divergent expectations as barriers to the diffusion of innovations. Am. J. Phys. Vol. 76, 79-92.

Physics Education Research _PER_ practitioners have engaged in substantial curriculum development and dissemination work in recent years. Yet, it appears that this work has had minimal influence on the fundamental teaching practices of the typical physics faculty. To better understand this situation, interviews were conducted with five likely users of physics education research. All reported making changes in their instructional practices and all were influenced, to some extent, by educational research. Yet, none made full use of educational research and most had complaints about their interactions with educational researchers. In this paper we examine how these instructors used educational research in making instructional decisions and identify divergent expectations about how researchers and faculty can work together to improve student learning. Although different instructors emphasized different aspects of this discrepancy between expectations, we believe that they are all related to a single underlying issue: the typical dissemination model is to disseminate curricular innovations and have faculty adopt them with minimal changes, while faculty expect researchers to work with them to incorporate research-based knowledge and materials into their unique instructional situations. Implications and recommendations are discussed.

Kalman, C., Aulls, M.W., Rohar, S., Godley, J. 2008. Students' perceptions of reflective writing as a tool for exploring an introductory textbook. Journal of College Science Teaching. March-April. 74-83.

This study explores how a specific academic activity', reflective writing, was perceived and accomplished by students in a gateway physics course. A survey, semi-structured interviews at the beginning, middle, and end of the course, and students' writing products were collected. Thematic and contents analysis showed this tool falls within the framework of Bereiter and

Scardamalia ,v knowledge transforming model of writing (1987). Students increase their knowledge acquisition through an interaction between content and discourse processes. Students understood that engaging in reflective writing enabled them to determine when they did not understand a concept as it was being read and that reflective writing promoted self-dialogue between the learners prior knowledge and new concepts in the textbook.

Lasry, N. 2008. Clickers or flashcards: Is there really a difference? The Physics Teacher. Vol. 26, 242-245.

A growing number of physics teachers are currently turning to instructional technologies such as wireless handheld response systems —colloquially called clickers. Two possible rationales may explain the growing interest in these devices. The first is the presumption that clickers are more effective instructional instruments. The second rationale is somewhat reminiscent of Martin Davis' declaration when purchasing the Oakland Athletics: "As men get older, the toys get more expensive." Although personally motivated by both of these rationales, the effectiveness of clickers over inexpensive low-tech flashcards remains questionable. Thus, the first half of this paper presents findings of a classroom study comparing the differences in student learning between a Peer Instruction group using clickers and a Peer Instruction group using flashcards. Having assessed student learning differences, the second half of the paper describes differences in teaching effectiveness between clickers and flashcards.

Lasry, N., Mazur, E., Watkins, J. 2008. Peer instruction: From Harvard to the two-year college. American Journal of Physics. Vol. 76, 1066-1070.

We compare the effectiveness of a first implementation of peer instruction _PI_ in a two-year college with the first PI implementation at a top-tier four-year research institution. We show how effective PI is for students with less background knowledge and what the impact of PI methodology is on student attrition in the course. Results concerning the effectiveness of PI in the college setting replicate earlier findings: PI-taught students demonstrate better conceptual learning and similar problem-solving abilities than traditionally taught students. However, not previously reported are the following two findings: First, although students with more background knowledge benefit most from either type of instruction, PI students with less background knowledge gain as much as students with more background knowledge in traditional instruction. Second, PI methodology is found to decrease student attrition in introductory physics courses at both four-year and two-year institutions.

Limbarkin, J. 2008. Concept inventories in higher education science. A manuscript prepared for the National Research Council Promising Practices in Undergraduate STEM Education Workshop 2 Washington, D.C.

Concept inventories (CIs) are multiple-choice assessment tests ideally designed for two learner-focused purposes. At their most useful, CIs can be used to diagnose areas of conceptual difficulty prior to instruction, and evaluate changes in conceptual understanding related to a specific intervention. Some CI developers (e.g Klymkowsky, and Garvin-Doxas, 2008) focus predominantly on diagnosis, while other efforts (e.g., Anderson et al., 2002, Libarkin and Anderson, 2007) work towards assessment tools that can serve the dual purposes of assessment as well as diagnosis. Regardless of the ultimate purpose of a CI, they are a valuable and necessary first-step in efforts to investigate learning in science fields across institutional settings.

Mulhall, P., Gunstone, R. 2008. Views about physics held by physics teachers with differing approaches to teaching physics. Res Sci Educ. Vol. 38, 435-462.

> Physics teachers’ approaches to teaching physics are generally considered to be linked to their views about physics. In this qualitative study, the views about physics held by a group of physics teachers whose teaching practice was traditional were explored and compared with the views held by physics teachers who used conceptual change approaches. A particular focus of the study was teachers’ views about the role of mathematics in physics. The findings suggest the traditional teachers saw physics as discovered, close approximations of reality while the conceptual change teachers’ views about physics ranged from a social constructivist perspective to more realist views. However, most teachers did not appear to have given much thought to the nature of physics or physics knowledge, nor to the role of mathematics in physics.

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.

Dreifus, C. Using the ‘beauties of physics’ to conquer science illiteracy. The New York Times. July, 17, 2007. http://www.nytimes.com/2007/07/17/science/17conv.html?_r=1&oref=slogin&ref=science.

> In the halls of academia, it is the rare senior professor who volunteers to teach basic science courses to undergraduates. But Eric Mazur, the Gordon McKay Professor of Applied Physics at Harvard, is driven by a passion. He wants to end science illiteracy among the nation’s college students; specifically, he strives to open them to the “great beauties of physics.”

Hake, R. 2007. Six lessons from the physics education reform effort. Lat. Am. J. Phys. Educ. Vol. 1, 24-32.

> In a 1998 meta-analysis I showed that “interactive engagement” (IE) courses could yield average normalized pre-to-posttest gains <g> in conceptual understanding of Newtonian

mechanics that were about two standard deviations greater than traditional (T) courses. Then in 2002 I wrote a paper based on my meta-analysis entitled “Lessons From the Physics Education Reform Effort.” There, among other things, I offered six lessons on “interactive engagement” that I had hoped might stimulate more effective high school and university education. Today five years later, it may be worthwhile to review and update those lessons with an eye to the present status of education reform in physics and their disciplines.

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.

Hrepic, Z., Zollman, D.A., Rebello, N.S. 2007. Comparing students’ and experts’ understanding fo the content of a lecture. Journal of Science Education and Technology. Vol. 16, 213-225.

> In spite of advances in physics pedagogy, the lecture is by far the most widely used format of instruction. We investigated students’ understanding and perceptions of the content delivered during a physics lecture. A group of experts (physics instructors) also participated in the study as a reference for the comparison. During the study, all participants responded to a written conceptual survey on sound propagation. Next, they looked for answers to the survey questions in a videotaped lecture by a nationally known teacher. As they viewed the lecture, they indicated instances, if any, in which the survey questions were answered during the lecture. They also wrote down (and if needed, later explained) the answer, which they perceived was given by the instructor in the video lecture. Students who participated in the study were enrolled in a conceptual physics course and had already covered the topic in class before the study. We discuss and compare students’ and experts’ responses to the survey questions before and after the lecture.

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 (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.

Ogan-Bekiroglu, F. 2007. To what degree do the currently used physics textbooks meet the expectations? J. of Sci Teacher Educ. Vol. 18, 599-628.

> Textbooks play an important part in the instructional process. The purposes of this study were to develop an instrument to identify the characteristics of high school physics textbooks, and examine how appropriate the currently used textbooks were for teaching and learning physics. The criteria were identified and the instrument was developed with the pre-service physics teachers to evaluate the physics textbooks approved by the Turkish Ministry of Education. This study described some problems in the content and design of the physics textbooks that might be caused by the narrow criteria used by the Ministry to approve science textbooks. The criteria in this evaluation instrument would provide an empirical base in analysis of high school physics textbooks and be used by not only the Turkish Ministry but also by physics teachers and textbook evaluators from other countries. Moreover, these criteria can be modified and used in selection of appropriate textbooks of other science disciplines.

Beatty, I.D., Gerace, W.J., Leonard, W.J., Dufresne, R.J. 2006. Designing effective questions for classroom response system teaching. American Journal of Physics. Vol. 74, 31-40.

> Classroom response systems can be powerful tools for teaching physics. Their efficacy depends strongly on the quality of the questions. Creating effective questions is difficult and differs from creating exam and homework problems. Each classroom response system question should have an explicit pedagogic purpose consisting of a content goal, a process goal, and a metacognitive goal. Questions can be designed to fulfill their purpose through four complementary mechanisms: directing students' attention, stimulating specific cognitive processes, communicating information to the instructor and students via classroom response system-tabulated answer counts, and facilitating the articulation and confrontation of ideas. We identify several tactics that are useful for designing potent questions and present four "makeovers" to show how these tactics can be used to convert traditional physics questions into more powerful questions for a classroom response system.

Podolefsky, N., Finkelstein, N. 2006. The perceived value of college physics textbooks: Students and instructors may not see eye to eye. The Physics Teacher. Vol. 44, 338-343.

> Physics instructors generally tell their students to read the textbook assignments before coming to lecture. While the textbook is a part of nearly every physics course, it is not clear how students use it. Only small number of previous studies has asked how students actually use their textbooks. One such study measured the amount students read a particular introductory physics textbook at two institutions. This study showed that at one institution less than 40% of students in introductory physics regularly read the textbook assignments, but that at an

institution where students were required to submit reading exercise, 55% of students regularly read the textbook. However, this study did not explore the effects of reading or whether different courses or different textbooks affected student reading habits. Another study, in chemistry, reported a significant correlation between the times spent reading and course grades for general chemistry students; lower performing students actually read more. This study, however, also reported that for organic chemistry students there was no correlation between times spent reading and course grades.

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.

Coletta, V.P., Phillips, J.A. 2005. Interpreting FCI scores: Normalized gain, preinstruction scores, and scientific reasoning ability. American Journal of Physics. Vol. 73, 1172-1183.

We examined normalized gains and preinstruction scores on the force concept inventory _FCI_ for students in interactive engagement courses in introductory mechanics at four universities and found a significant, positive correlation for three of them. We also examined class average FCI scores of 2948 students in 38 interactive engagement classes, 31 of which were from the same four universities and 7 of which came from 3 other schools. We found a significant, positive correlation between class average normalized FCI gains and class average preinstruction scores. To probe this correlation, we administered Lawson's classroom test of scientific reasoning to 65 students and found a significant, positive correlation between these students' normalized FCI gains and their Lawson test scores. This correlation is even stronger than the correlation between FCI gains and preinstruction FCI scores. Our study demonstrates that differences in student populations are important when comparing normalized gains in different interactive engagement classes.We suggest using the Lawson test along with the FCI to measure the effectiveness of alternative interactive engagement strategies.

Wieman, C., Perkins, K. 2005. Transforming physics education. Physics Today. November, 36-42.

The science community needs to change science education to make it effective and relevant for a much larger fraction of the student population than in the past. This need is the result of significant changes in the environment and society over the past several decades. First, society now faces critical global-scale issues that are fundamentally technical in nature – for example, climate change, genetic modification, and energy supply. Only a far more scientifically and technically literate citizenry can make wise decisions on such issues. Second, modern economies are so heavily based on technology that having a better understanding of science and technology and better technical problem-solving skills will enhance a person's career

aspirations almost independent of occupation. Furthermore, a modern economy can thrive only if it has a workforce with high-level technical understanding and skills.

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.

Ehrlich, R. 2002. How do we know if we are doing a good job in physics teaching? American J. Phys. Vol. 70, 24-30.

Whether it be at the level of the individual, the academic department, or the entire physics teaching profession, nearly all of us want to do a good job. But how can we know if we are succeeding? To what extent can we trust traditional measures of excellence in teaching, and what alternative measures resting on different—perhaps even unfashionable—assumptions might we consider?

Judson, E., Swada, D. 2002. Learning from past and present: Electronic response systems I college lecture halls. Journal of Computers in Mathematics and Science Teaching. Vol. 21, 167-181.

This article reviews literature from the past 33 years particular to the use of electronic response systems in college lecture halls. Electronic response systems, primarily used in science courses have allowed students to provide immediate feedback to multiple-choice questions, and inform the instructor of student understanding. Research from the 1960s and 1970s indicates there is no significant correlation between student academic achievement and a stimulus-response method of using such systems. Recent studies have indicated there is significant student increase of conceptual gains in physics when electronic response systems are used to facilitate feedback in a constructivist-oriented classroom. Students have always favored the use of electronic response systems and attribute such factors as attentiveness and personal understanding to using electronic response systems. Ultimately, this review of literature points to the pedagogical practices of the instructor, not the incorporation of the technology as being key to student comprehension. Electronic response systems are viewed as a tool that holds a promise of facilitating earnest discussion. Recommendations are made that professional development focus on pedagogical practice for instructors considering the use of electronic response system.

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.

McDermott, L.C. 2001. Oersted Medal Lecture 2001: “Physics education research – The key to student learning”. Am. J. Phys. Vol. 69, 1127-1138.

Research on the learning and teaching of physics is essential for cumulative improvement in physics instruction. Pursuing this goal through systematic research is efficient and greatly increases the likelihood that innovations will be effective beyond a particular instructor or institutional setting. The perspective taken is that teaching is a science as well as an art. Research conducted by physicists who are actively engaged in teaching can be the key to setting high (yet realistic) standards, to helping students meet expectations, and to assessing the extent to which real learning takes place.

Brent, R. Felder, R., Regan, T., Walser, A., Carlson-Dikes, C., Evans, D., Malave, C., Sanders, K., McGourty, J. 2000. Engineering faculty development: A multicoalition perspective. Paper presented at the Annual Meeting of the American Society for Engineering Education (St. Louis, MO, June 18-21).

This paper addresses the issue of faculty participation in development programs. Participation in faculty development programs has not been part of the culture in engineering education and with the focus on reform, ways are being sought to involve faculty in retraining. At North Carolina State University (NCSU), representatives from the NSF-sponsored Engineering Education Coalition (EEC) decided to use a faculty development model. Details of this model are presented.

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.

Hake, R.R. 2000s, Interactive-engagement vs traditional methods: A six-thousand-student survey f mechanics test data for introductory physics courses. American Journal or Physics.

> A survey of pre/post test data using the Halloun-Hestenes Mechanics Diagnostic test or more recent Force Concept Inventory is reported for 62 introductory physics courses enrolling a total number of students N = 6542. A consistent analysis over diverse student populations in high schools, colleges, and universities is obtained if a rough measure of the average effectiveness of a course in promoting conceptual understanding is taken to be the average normalized gain <g>. The latter is defined as the ratio of the actual average gain (%<post> – %<pre>) to the maximum possible average gain (100 – %<pre>). Fourteen "traditional" (T) courses (N = 2084) which made little or no use of interactive-engagement (IE) methods achieved an average gain <g>T-ave = 0.23 ± 0.04 (std dev). In sharp contrast, forty-eight courses (N = 4458) which made substantial use of IE methods achieved an average gain <g>IE-ave = 0.48 ± 0.14 (std dev), almost two standard deviations of <g>IE-ave above that of the traditional courses. Results for 30 (N = 3259) of the above 62 courses on the problem-solving Mechanics Baseline test of Hestenes-Wells imply that IE strategies enhance problem-solving ability. The conceptual and problem-solving test results strongly suggest that the classroom use of IE methods can increase mechanics-course effectiveness well beyond that obtained in traditional practice.

Hake, Richard. 1998. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. Am. J. Phys. Vol. 66, 64-75.

> A survey of pre/post-test data using the Halloun–Hestenes Mechanics Diagnostic test or more recent Force Concept Inventory is reported for 62 introductory physics courses enrolling a total number of students *N*56542. A consistent analysis over diverse student populations in high schools, colleges, and universities is obtained if a rough measure of the average effectiveness of a course in promoting conceptual understanding is taken to be the average normalized gain ^*g*&. The latter is defined as the ratio of the actual average gain (%^post&2%^pre&) to the maximum possible average gain (100 2%^pre&). Fourteen ‘‘traditional’’ (*T*) courses (*N*52084) which made little or no use of interactive-engagement ~IE! methods achieved an average gain ^*g*&*T*-ave50.2360.04 ~std dev!. In sharp contrast, 48 courses (*N*54458) which made substantial use of IE methods achieved an average gain ^*g*&IE-ave50.4860.14 ~std dev!, almost two

standard deviations of ^*g*&IE-ave above that of the traditional courses. Results for 30 (*N*53259) of the above 62 courses on the problem-solving Mechanics Baseline test of Hestenes–Wells imply that IE strategies enhance problem-solving ability. The conceptual and problem-solving test results strongly suggest that the classroom use of IE methods can increase mechanics-course effectiveness well beyond that obtained in traditional practice.

Heller, P., Keith, R., Anderson, S. 1992. Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. American Journal of Physics. Vol. 60, 627-637.

An experiment was conducted to investigate the effects of cooperative group learning on the problem solving performance of college students in a large introductory physics course. An explicit problem solving strategy was taught in the course, and students practiced using the strategy to solve problems in mixed-ability cooperative groups. A technique was developed to evaluate students' problem solving performance and determine the difficulty of context-rich problems. It was found that better problem solutions emerged through collaboration than were achieved by individuals working alone. The instructional approach improved the problem solving performance of students at all ability levels.

Heller, P., Hollabaugh, M. 1992. Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups. American Journal of Physics. Vol. 60, 637-645.

A supportive environment based on cooperative grouping was developed to foster students' learning of an effective problem-solving strategy. Experiments to adapt the technique of cooperative grouping to physics problem solving were carried out in two diverse settings: a large introductory course at state university, and a small modern physics class at a community college. Groups were more likely to use an effective problem-solving strategy when given context-rich problems to solve than when given standard textbook problems. Well-functioning cooperative groups were found to result from specific structural and management procedures governing group members' interactions. Group size, the gender and ability composition of groups, seating arrangement, role assignment, textbook use, and group as well as individual testing were all found ton contribute to the problem-solving performance of cooperative groups.

Prosser, M., Millar, R. 1989. The <How> and <What> of learning physics. European Journal of Psychology of Education. Vol. 4. 513-528.

Recent research on student learning in higher education has increasingly focused on experiential aspects of how students approach their studies and what they learn from their studies. In this paper we describe the results of a study using phenomenographic research techniques, which focusses on student learning in a first year university physics course. The study, using interviews with sixteen volunteer students from the course, shows that only those students who actively sought to change their conceptions of the subject matter did so, while those who sought only to reproduce that subject matter did not.

Halloun, I.A., Hestenes, D. 1985. The initial knowledge state of college physics students. Am. J. Phys. Vol 53, 1043-1056.

An instrument to assess the basic knowledge state of students taking a first course in physics has been designed and validated. Measurements with the instrument t show that the student's initial qualitative, common sense beliefs about motion and causes has a large effect on performance in physics, but conventional instruction induces only a small change in those beliefs.