

PROCEEDINGS:

SYMPOSIUM ON REFORM IN UNDERGRADUATE SCIENCE

The University of Alabama
Tuscaloosa, Alabama

January 18, 2008

There is a reform movement because we need to teach science to non-majors. This is a typical response on campus. In a traditional sense, knowledge is given. Here is the knowledge in an envelope and this is yours. In a non-traditional course, students are helping to create knowledge in their own minds.

Dr. Kevin Whitaker

Dr. Dennis W. Sunal and Dr. Cynthia Szymanski Sunal

Traditional lecture based courses are an ineffective way to foster undergraduate student learning in science. Students retain little of the information covered in lectures, yet lectures remain the way information is delivered to students. If educators in the field of science are truly interested in creating a more science literate public, a change in how science is portrayed in the classroom has to occur. Educators need to become aware of how their own beliefs about science affect their instructional practice and student learning. STEM reform in higher education is being urged nationally on a regular basis. Higher education faculties are attempting to improve the effectiveness of undergraduate science courses. There is a need to build a consensus on the definition of a reformed course, on course characteristics that produce a significant impact on students, and on the characteristics of effective faculty and teaching in college classrooms. On Friday, January 18, 2008 a Symposium in Reform in Undergraduate Science co-sponsored by The Office of Research on Teaching in the Disciplines, the Department of Curriculum and Instruction, the College of Arts and Sciences, the College of Education, and the College of Engineering, was held at the University of Alabama. The goal was to create a dialog

about the meaning of reform in entry level science courses and to establish a discourse between researchers in the education field and scientists. Five questions were addressed:

1. What does it mean to say that an undergraduate science course is traditional or that one is reformed?
2. How do course characteristics differ between reform and traditional undergraduate science courses and how does this relate to the learning outcomes of undergraduate students?
3. How do the levels of reform science course characteristics differ between reform courses and how do these differences relate to the learning outcomes of undergraduate students?
4. What are the necessary characteristics to say an undergraduate science course is innovative or reformed?
5. How do we address the underlying STEM pipeline dilemma? What science and what type of science teaching is needed for teachers in classrooms to create students who want to enter college and have the pre-requisite ability, interest, and knowledge to successfully complete STEM majors?

What is a Reformed Course?

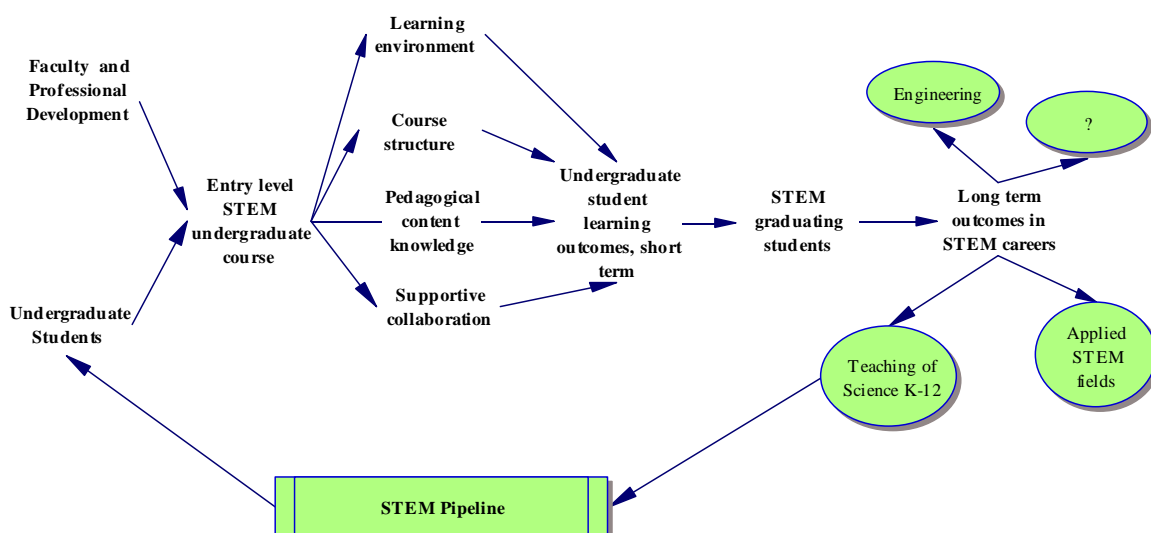
Several characteristics of a reformed course can be identified. The most prevalent features of a reformed course are the switch from teacher centered learning to student centered learning and to alternative forms of assessment. Some of the characteristics of the courses discussed in this Symposium include:

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|---|---|
| <ul style="list-style-type: none"> • Active learning | <ul style="list-style-type: none"> • Alternative and team teaching |
| <ul style="list-style-type: none"> • Classroom real-time feedback | <ul style="list-style-type: none"> • Cooperative grouping for in-class assignments |
| <ul style="list-style-type: none"> • Use of a learning cycle | <ul style="list-style-type: none"> • Online assessments |
| <ul style="list-style-type: none"> • Connection to everyday experience | <ul style="list-style-type: none"> • Frequent assessment |
| <ul style="list-style-type: none"> • Connection to current events | <ul style="list-style-type: none"> • Incorporates technology |
| <ul style="list-style-type: none"> • Collaborative lab work among students | <ul style="list-style-type: none"> • Self-paced, no lectures |
| <ul style="list-style-type: none"> • Mentoring • Teaming and competitions | <ul style="list-style-type: none"> • Group for out of class projects |

| | |
|--|--|
| <ul style="list-style-type: none"> • Innovative/creative assignments | <ul style="list-style-type: none"> • Class assessment of group projects |
| <ul style="list-style-type: none"> • Integration of lectures and labs | |

These characteristics can be put into six categories; (1) assessment, (2) collaboration, (3) active learning, (4) relevance, (5) technology, and (6) innovative instruction.

A generalized research model being used by NSEUS was presented as part of the discussion. This research path encompassed the STEM Pipeline during students' progress and achievement in their undergraduate studies as indicated in the figure below.



What Do Reform Courses Look Like in Practice?

Five innovative courses were presented at the Symposium. While none of the courses contained all of the characteristics found in reformed courses, each of them contained aspects of a reformed course that has an impact on student learning.

Dr. Julie Olson

Dr. Julie Olson discussed the studio biology course currently being offered to non-science majors by the Department of Biological Sciences (BSC 108). This course, BSC 108, is an introductory biology course for non-majors that was first offered in 2004. Unlike the traditional introductory biology course, BSC 108 has fewer students, the learning is student centered, self-paced *PowerPoint* presentations are used in place of lectures, innovative assessment and instruction are utilized, and technology is a big part of the course. Students are made responsible for their own learning and are able to learn the material at their own pace. There is no discord between the laboratory portion and the lecture portion of the course, because the two are integrated. The students get hands-on experience with the concepts being presented. The changes that were made in the

studio biology course were made with student learning in mind. Student feedback suggests that students participating in BSC 108 were more satisfied with their learning and ability to communicate their ideas than were students participating in the traditional introductory biology course. Feedback results are shown in Table 1.

Literature on student learning in science at the college level indicates that allowing students to own their own learning increases their ability to gain knowledge of the concepts being presented (Eisenkraft, 2003, McDonald & Dominguez, 2005). Abolishing traditional lectures and replacing them with group discussions, research projects, literature searches etc. is a common way to allow students to discover their ideas about a concept and replace any misconceptions they hold. (Cameron, 2003; Lodish, Rodriguez, & Klionsky, 2004). It is evident from the results in Table 1, that the students participating in BSC 108 were more confident in their learning of the concepts than were those attending the traditional lecture based course.

| Table 1: Student Feedback- Core class evaluation survey data for the lecture-based class and the studio course (BSC 108): | | | | | |
|---|-----------|----------|-------------|------------|-----|
| Overall, did the way this course was taught have a positive impact on your learning? | | | | | |
| BSC108 | Y, 93% | | | N, 7% | |
| Lecture-Based | Y, 71.4 | | | N, 28.6 | |
| To what extent did this class contribute to your ability to use facts to get points across to others? | | | | | |
| | Very Much | Somewhat | Very Little | Not at All | N/A |
| BSC 108 | 63.9 | 25.0 | 8.3 | 2.8 | 0.0 |
| Lecture-Based | 19.8 | 45.2 | 18.3 | 11.1 | 5.6 |

Dr. Stan Jones

Another example of decreasing the amount of time students spent in lectures was presented by **Dr. Stan Jones** from the Department of Physics at the University of Alabama. The Studio Physics course features integrated lectures, labs, active learning, interactive exercises (predict, do, explain), technology, and a 20/1 student/teacher ratio. The traditional introductory physics course has separate laboratory and lecture. Students attend a lecture three times a week and have a laboratory section once a week. In the studio physics course, students are allowed to interact with the concept and engage in active learning. Students are confronted with the concept under study multiple times. In

the traditional physics course, there is no active engagement and the students may only

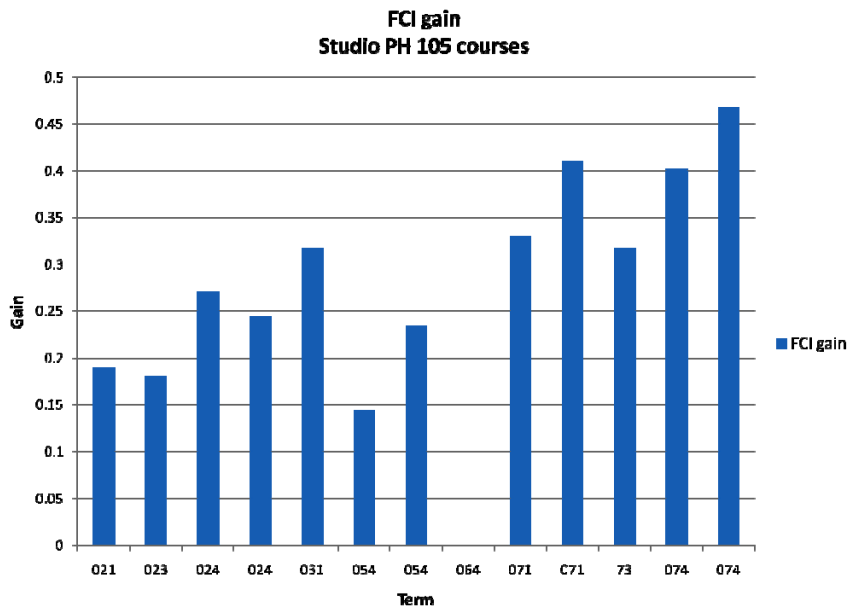


Chart 1:

Conceptual Gain as measured by the Force Concept Inventory (Hestenes *et al.*, 1992, 1995) for the sessions of Studio Physics offered between 2002-2007.

From Dr. David Jones. 2008

confront the concept once.

Students in the Studio Physics section show gains in conceptual learning as measured by the *Force Concept Inventory* (Hestenes *et al.*, 1992, 1995). Results are shown in Chart 1. A comparison to the traditional physics is not shown. After several years of teaching the course, the students in the studio physics course show a gain of 40% while the students in the traditional course only show a gain of 15%.

Dr. David Cordes

Much of the literature on reform focuses on student learning of the content area. While student learning of course work is certainly a goal of college professors, the job goes beyond that. One of these goals is to act as a mentor for students attempting to enter into their field of study. College professors in the sciences are training the next generation of scientist. Most students enter college with no idea of what it really means to be a scientist. Simply having students attend lectures is not going to help in this training. *Dr. David Cordes* discussed changes that were made in freshman engineering and computer science courses that, in addition to the common features of a reformed course, had the goal of acclimating students to college life, helping students understand what it means to be an engineer, and maintaining student ties with the department during their freshmen year. Many students take core courses during their freshmen year and lose ties with the department because they are fulfilling general education requirements. Student mentors were added as a solution to keep students majoring in engineering and computer science in contact with their department. The mentors served both an academic and social purpose.

When many students enter college, they have a rough idea of what it is they want to do. The introductory course, discussed by Dr. Cordes, in computer sciences was changed to give students hand on experience with computers. A hands-on experience with computers provides students with a better opportunity to learn about computers than does watching others do it. It allows the students to develop a better understanding of what they do and do not know and it allows them to get a better idea of what they want to focus on in their careers.

Dr. Sanjay Rabello

Classroom size is a common argument against course reform, but examples in the literature say it should not be (Lodish, Rodriguez, & Kliensky, 2004; Pukkila, 2004; Zollman, 2004; Howard & Miskowski, 2005). *Dr. Sanjay Rabello* presented a reformed physics course offered at Kansas State University for students planning to become elementary school teachers. It was first offered in 1979 and is highly recommended by Elementary Education faculty. Approximately half of Elementary Education majors take the course, although it is not required. The class is a large class, showing that reform can occur in large class settings; about 100 students per session. Instruction is based on the learning cycle (Karplus, 1977) which is a three part sequence designed to engage students in the content during the exploration phase, allow students to experience a conceptual change during the explanation phase, and allow students to apply their new knowledge to similar concepts. Monday is the exploration phase of the learning cycle during the course. In this phase, students perform and record results from experiments. The explanation phase of the cycle occurs on Wednesday. The instructor introduces the concept to the students and explains the observations that were made earlier in the week. The application phase occurs on Fridays. The students use worksheet guided activities to practice working with the new concepts they have learned, allowing them to develop an even deeper understanding of the concept. The class also makes use of PDA systems to allow the class to be interactive and students and teachers to get real-time feedback. The students interact with each other online through pod-casts and chartrooms. The use of the

learning cycle engages the students in the content and allows for conceptual change and learning to occur.

Dr. Garry Warren

Science is presented as a set of facts to be memorized and students see it as being irrelevant to their lives and they become disengaged. If learning is to occur, the content has to be relevant and students have to be engaged. The use of non-scientific literature is a way to get students interest in the content. ***Dr. Garry Warren***, a Professor in Metallurgical and Materials Engineering at the University of Alabama, presented on MTE 155 Energy, Environment & Materials. He describes MTE 155 as essentially freshman chemistry but with a twist. In traditional courses, science is presented as a set of facts. It often seems irrelevant to students. In MTE 155 science is presented in a context of social, political, economic, and ethical issues. The course connects the fundamental concepts of chemistry to issues the students hear in the news. Students collect news articles relating to each chapter covered in class. Bernard Strauss (2005), in describing methods to teach genetics to non-science majors, suggested that using the New York Times (or other non-scientific publications) could be used in instruction. All undergraduates can benefit from seeing the impact that science has on our everyday lives. Issues such as cloning, stem cell research, global warming, and alternative fuels can act as starting points concepts presented in classes for majors and non-majors. Articles on controversial issues can lead to the realization that science is not just a set of facts to be memorized, and that science is important for everyone to understand.

Conclusion

Most college professors are aware of the need to change the way in which they teach. Many professors in the sciences are unaware of what instructional practice work effectively in the classroom. If they are aware of the instructional practices, they are unaware of how to implement the necessary changes to create a reformed course. Some professors remain skeptical of the techniques used in reformed course because of the lack of research at the college level. An audience member stated:

Audience member: I have many colleagues that are not convinced that inquiry-based and other reform pedagogy is effective. Is there longitudinal data to illustrate these techniques are as effective as or more effective than traditional pedagogy?...The literature base in the discipline does not always provide support for the use of reform pedagogy.

The lack of research on instructional practices that work in the college classroom was raised at the symposium. The problem of the paucity of research in science teaching can be resolved. It has to start in the classroom in the form of action research projects. Change will not occur until instructors begin to make the change.

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