AN INTRODUCTION TO STEMTEC AND "PATHWAYS TO CHANGE"

C. D'AVANZO
School of Natural Sciences, Hampshire College
Amherst, MA 01002
cdavanzo@hampshire.edu
R. F. YURETICH
Dept. of Geosciences, University of Massachusetts Amherst
Amherst, MA 01003
yuretich@geo.umass.edu

STEMTEC is the Massachusetts Collaborative for Excellence in Teacher Preparation. The first step in preparing future teachers is to have them experience effective teaching in college science and mathematics courses. The Science, Technology, Engineering, and Mathematics Teacher Education Collaborative (STEMTEC) summer institutes familiarized 150 faculty members with a variety of teaching strategies recommended in the National Science Teaching Standards. These faculty incorporated the techniques into one or more of their courses during subsequent academic years, and many of them reported on their progress during a research conference, "Pathways to Change," which STEMTEC sponsored in the summer of 2000. Eleven papers, based on these conference reports, are included in this volume.

STEMTEC: A Brief Overview

STEMTEC (Science, Technology, Engineering, and Mathematics Teacher Education Collaborative) is the Massachusetts Collaborative for Excellence in Teacher Preparation (CETP), funded by the National Science Foundation in 1997. During a seven-year period starting in 1992, the Division of Undergraduate Education (DUE) established twenty CETP sites around the nation with the purpose of drawing more and better qualified undergraduates into K-12 science and mathematics teaching. Although each CETP program has this common goal, the sites differ in emphasis and approach.

STEMTEC initiated a comprehensive effort to improve the quality of teaching by science and mathematics faculty as a stimulus for undergraduates to consider careers in K-12 teaching. We reasoned that students would become more interested in these subjects, and also in teaching, if their own college professors were aware of good pedagogical practices, especially those recommended by the National Science Teaching Standards [1]. Numerous studies published between 1986 and 1997 show that good students are leaving science, mathematics, and engineering majors because of poor teaching, especially in introductory courses [2,3]. Teaching techniques in these courses typically emphasize memorization, coverage, and competition, whereas the recommendations for effective teaching and learning call for greater emphasis on the

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process of science, inquiry, and cooperative learning [1,4,5,6]. Many college professors were unaware of these recommendations, or of the research upon which they are based.

As a group, university science professors are notoriously resistant to changing how and what they teach. In our STEMTEC video, *How Change Happens: Breaking the Teach As You Were Taught Cycle in Science and Math*, Dean Linda Slakey of the University of Massachusetts (UMass) Amherst says that getting university science and mathematics faculty to focus on teaching improvement is often " ... like herding cats. We hire them because they are good at what they do..." referring primarily to their ability to do research in their respective academic disciplines. In addition, most college faculty have had little or no training in pedagogy and theories of cognition or in the principles and methods of evaluation. So we designed a very ambitious program of summer institutes, follow-up sessions, and implementation, to familiarize college faculty with these aspects of teaching.

The faculty development aspect of STEMTEC has involved nearly 25% of the college science and mathematics faculty in the original eight-college collaborative (Amherst College, Greenfield Community College, Hampshire College, Holyoke Community College, Mount Holyoke College, Smith College, Springfield Technical Community College, and the University of Massachusetts Amherst). Over three years, we ran summer institutes for eighty faculty members in biology, chemistry, geology, physics, and mathematics who contracted to redesign at least one of their courses using the principles learned at the institute. The faculty were organized into teams by discipline to investigate common themes that could be pursued in redesigning undergraduate courses. Each team included two K-12 teachers who served as pedagogical experts in assisting the college faculty in their task. The collaborative expanded in 1999 and 2000 to include faculty from other colleges throughout Massachusetts where teacher training was emphasized. Participation from fifteen additional colleges increased the number of faculty who have taken our workshops to 150.

"Pathways to Change" is an important outcome of these STEMTEC institutes. In place of a follow-up institute for our original participants in the summer of 2000, we conceived the idea of a model research conference, where faculty members could showcase their accomplishments under the STEMTEC program. These include the redesign of undergraduate courses, new assessment strategies, and mechanisms for bringing students into K-12 classrooms and other teaching settings. This conference featured STEMTEC college and K-12 faculty from a wide range of disciplines and institutions who gave presentations and were discussion leaders. Several

of the presenters prepared manuscripts based on their contribution, and these constitute the proceedings of "Pathways to Change," the first part of this journal volume.

STEMTEC Course Redesign and Recommended Pedagogical Practices

The authors in this collection of papers refer to particular pedagogical practices advocated during the STEMTEC institutes, such as Problem Based Learning (PBL), alternative assessment (e.g., "the pyramid exam"), and K-16 collaborations. To put these references in context, we describe relevant aspects of the summer program.

During the summer institutes, we invited session leaders who were well known for their ability to introduce college faculty to current research in teaching and learning, and demonstrate practical applications to the college classroom. These facilitators focused on several components of student-active methods that are discussed in the articles that follow. Some terms and concepts that the authors mention are explained more fully below.

- Cooperative Learning is characterized by both group and individual accountability. Group members are responsible for their own learning and that of the entire group. Groups are small (typically 3-5), teamwork skills are emphasized, and members share group roles with frequent processing of group effectiveness.

  Positive Interdependence – students work together to accomplish a task in which success depends on participation by each person.

  Informal Groups – these are typically used to break up a lecture and in large classes; students are not assigned specific roles and structure is minimal; can be ad hoc, as in "think-pair-share."

  Formal Groups – students assume specific roles (e.g., facilitator, skeptic, recorder, reporter).

  Problem Based Learning (PBL) – PBL was developed by medical schools in the 1950's and has been adapted for a variety of teaching situations. Students are given a problem or a puzzle "cold" (such as the symptoms of an ill patient) and work together in formal groups to discuss what is known, develop possible hypotheses about the problem, and work together to find and synthesize information needed to solve it.

- Alternative Assessment refers to modifications or replacements for the traditional, in-class individual exam as a way of measuring student performance.

  Pyramid Exam – This exam was developed at Smith College [7] in order for students in calculus classes to work both alone and in cooperative groups on realistic, very

challenging questions for a test. The process builds on itself (is a "pyramid") and allows students to work alone and in groups on the same test over several days. STEMTEC faculty have modified the exam for students in large classes as a one-hour "two step" exam. In this modification, students take the test alone and hand it in; they then work in informal groups with other students and retake the test either as a group or individually. Other variants include giving students a chance to reason through their incorrect answers after the exam and to explain why their answers were wrong (and the correct answer was right).

- Evaluation is used primarily to refer to feedback from students on the impact of teaching methods or their learning experiences.

  Formative evaluation – looks at the course (or project) all along the way and its purpose is to give ongoing diagnosis and feedback so that professors can change their teaching if needed. It is diagnostic, non-judgmental, private, often anonymous, and specific [8].

  Summative evaluation – this is the familiar end-of-semester course evaluation, usually done in a multiple-choice format.

- Instructional technology refers primarily to computer-based methods to enhance learning and the classroom environment. This includes presentation software, web-based instructional tools and electronic classroom communication systems.

  Classtalk – this is a classroom technology that allows students to electronically register answers to questions posed in class and immediately displays the classes' responses on histograms displayed in front of the classroom. *Classtalk* gives faculty and students quick feedback to questions designed to uncover fundamental misconceptions and lack of understanding. A wireless version of this technology, called the Personal Response System (PRS) is now being introduced into some courses.

  OWL – On-line Web-based Learning is a way that students can complete quizzes and homework assignments interactively. The usual application is to have students complete a series of multiple-choice questions about a topic in the reading or discussed in class. OWL is set up so that if a student picks the wrong answer, the question is re-phrased, with new choices. The design helps ensure that students answering correctly will understand the reasoning behind their answer.

- Teaching experiences involve making the student an instructor on some level. The preferred mode is to have students teach in K-12 classroom settings in order to have a real taste of what the profession is all about.

The "Pathways to Change" Papers

The eleven articles that follow were all presented as oral contributions during our first "Pathways to Change" conference in June 2000. They are grouped by discipline, so that readers can find teaching and learning accomplishments aligned with their own areas more easily. Within each discipline, the papers are grouped alphabetically by senior author. Although most of the articles discuss specific courses and the changes in teaching and learning that have occurred within them, a few deal with more general methods that are helpful in improving science and mathematics education or the preparation of prospective teachers. The following table will help in finding the pedagogical practices highlighted in the articles:

Discipline	Author	Cooperative Learning	Alternative Assessment	Evaluation	Instructional Technology	Teaching Experiences
Biology	Bruno	PBL				
Biology	Kunkel	Projects	Writing		Web	
Biology	Prattis					K-12
Biology	Rapoport			Formative, Summative		K-12
Chemistry	Tyson	Groups	Pyramid Exams Writing	Summative		K-12
Engineering	Ganz	Groups Projects	Pyramid Quizzes	Summative	Interactive Web	
Mathematics	Connors	Groups	Projects		Presentation	
Mathematics	Peelle	Groups	Various		Computers	
Mathematics	Eisenberg	Groups	Pyramid Exams	Summative	*Mathematica*	
Physics	Mullin	Groups	Pyramid Exams Projects, Essays		PRS Website	Student TA
Physics	Rabin	Groups	Pyramid Exams	Summative	*Classtalk* OWL	

The Impact of STEMTEC on the Teaching of Science and Mathematics

These articles represent a small number of faculty members who changed their teaching as a result of the STEMTEC program. Many more were evaluated through case studies, student surveys, faculty surveys, and classroom observations. Detailed description of the substantial evaluation findings is beyond the scope of this introduction, but we include some highlights.

Case studies of several STEMTEC courses document numerous improvements in courses taught by faculty who had taken STEMTEC workshops [9]. These changes include increased class attendance, interest in the subject matter, greater confidence in their ability to be successful in technical courses, better understanding of the process of science, and increased interest in K-12 teaching. Student survey data show that students still spent a significant amount of time listening and taking notes in STEMTEC courses, but interaction among the students, and between the class and the instructor, increased noticeably. The following activities were also reported as taking place "about half the time": 1) working in small groups or pairs; 2) solving problems or answering open-ended questions during class; and, 3) giving formative feedback to the instructor. STEMTEC students were more likely to be interested in taking more science and math courses, they liked the subject matter more, and they agreed that hands-on activities should come before introduction of new vocabulary [10].

We have made a good start in improving the teaching and learning in a wide variety of science, mathematics, and engineering courses within our Collaborative. We are now in the process of using the courses that have been most successful in their changes as a nucleus of choices recommended for students who wish to be future science or math teachers. ■

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Bios

Charlene D'Avanzo is Professor of Ecology at Hampshire College. She has written numerous articles and edited books about student-active teaching, and she spearheaded

production of the STEMTEC video, *How Change Happens: Breaking the Teach As You Were Taught Cycle in Science and Math.*

Richard Yuretich is a professor in the Department of Geosciences at the University of Massachusetts Amherst. He has helped transform the learning environment in a very large, general education oceanography course by applying the techniques mentioned in this article. Both authors are Principal Investigators of STEMTEC.

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