Journeys: Monograph prepared for the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC) Project

Richard Stebbins PhD
University of Southern Maine

Amy Johnson
Maine Mathematics and Science Teaching Excellence Collaborative

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USM UMaine
MMSTEC Maines Mathematics & Science Teaching Excellence Collaborative

Project Address:
Richard Stebbins, *professor of chemistry*
Department of Chemistry
161 Science Building

University of Southern Maine
P.O. Box 9300
Portland, Maine 04104-9300

(207) 780-4449
FAX: 228-8288
e-mail: hawaiiki@usm.maine.edu
http://www.EducateMe.info

Principal Investigators:
Richard Stebbins, project director
University of Southern Maine

Francis Eberle
Maine Mathematics and Science Alliance

Robert Franzosa
University of Maine

Mary Schwanke
University of Maine at Farmington

Herman Weller
University of Maine

Collaborative Partners:
Maine Mathematics and Science Alliance
University of Southern Maine
University of Maine
University of Maine at Farmington
University of Maine at Machias
University of Maine at Presque Isle

A Personal Reflection on Mathematics/Science Education

I graduated from Wesleyan University in 1965 with a B.A. in Chemistry, and from Texas A&M University in 1970 with a Ph.D. in Physical Chemistry. For the next 13 years, I taught chemistry at a small private liberal arts college, and then at the University of Southern Maine (USM), a campus of the University of Maine System serving approximately 11,000 students per semester. In 1988, I became Associate Dean of the College of Arts and Sciences at USM, and in 1992, I became Dean of the College. In 1997, I stepped down from that position, rejoined the faculty, and eventually became Principal Investigator (PI) for the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC), the Maine National Science Foundation (NSF) Collaboratives for Excellence in Teacher Preparation (CETP) grant. During my 36 years in academia, I have taught mostly upper level chemistry courses, had some good stretches of research and scholarship, and a heavy dose of administration.

When I returned from a sabbatical at the University of Botswana in June 1998, and at that point having spent the previous nine years administering, I was confronted by the decision of how best to use my remaining time as an academic. I could "play with molecules", re-enter administration at the level of Provost, or attempt to improve K-16 mathematics and science learning through an NSF-sponsored CETP grant. I chose the latter.

My two criteria for making that decision were:

- I had to have passion for whatever undertaking I chose, and
- I had to believe that what I did would have the potential to make a difference to the State of Maine.

There were three major factors that influenced this decision. First, I am the father of three daughters, all raised in an era when women were not expected to enjoy or achieve success in mathematics or science. I became involved in their education and their schools, and thought that surely we should not treat half of our population in such a shoddy manner.

Second, as a research chemist, the first thing I always did was to go to the library and conduct a literature search on what was known about the subject. After teaching for 20 years, and having spent the majority of my university life teaching, I began to wonder why I had seldom consulted educational literature to inform myself about how people learn science. I think that there are as many answers to this question as there are questions, but a common theme underlying most of the answers is the separateness of the scientific and educational communities, and the explicit and implicit distrust between the two groups. As time passed, the drumbeat of this question has grown louder in my head, and I believe that with new information gleaned from cognitive science, scientists, and science educators, it is more important than ever for us to base our teaching on good scholarship that elucidates how students learn.

Third, in my time as Associate Dean and Dean of the College of Arts and Sciences, I was involved in a number of collaborations with the Dean of the College of Education and Human Development (CEHD). Through these experiences, I became familiar with USM teacher certification programs, the nature of mathematics and science education statewide, the National Council for Accreditation of Teacher Education (NCATE) accreditation process, and the work of the National Network for Educational Renewal (NNER) based in Seattle, Washington. I worked hard to improve mathematics and science education at USM and learned much. Through time spent with CEHD faculty and staff, I learned to value, and then trust most. With trust came the ability to listen closely, and to learn. Through this mix of personal experiences and values, I arrived at my current destination. It has been a good choice. I hope that I have made a difference.

The information contained in the sections following this personal reflection is included so that the stories of change written by grades 6-16 educators that constitute the "heart" of the monograph are seen within the local context. You will find information on the MMSTEC grant, MMSTEC partners, Maine schools, the University of Maine System (UMS), and MMSTEC overall goals, and some of what we think we accomplished.

Dick Stebbins
Professor of Chemistry, MMSTEC Principal Investigator
University of Southern Maine
Portland, Maine
hawaiiki@usm.maine.edu

Editor's Note

Dear Reader:

As the MMSTEC project entered its fifth year, our thoughts inevitably turned to the closure of our efforts. What progress had we made? What did we learn? How could we capture this learning to ensure its longevity? And how can we disseminate our ideas to our peers? As many projects before us have done, we decided to gather and compile the stories that illustrate our experience, both for our collective memory and for perusal by other educators.

Because MMSTEC has gone to great lengths to garner meaningful participation from all segments of the 6-16 mathematics and science public education world—6-12 and post-secondary, education and content areas, pre-service through seasoned teachers—we wanted our monograph to include perspectives from each of these groups. We issued a call for papers with a guiding theme of "change." The call invited project participants to share with us aspects of their journeys as they explored new and different ideas, made changes in their practices, and subsequently grew as educators over the course of the MMSTEC initiative. In some cases where we anticipated reluctance, we directly solicited authors whose experiences we thought would help to fill in the complete picture of our work.

After scanning the first round of submissions, we were surprised by the breadth of themes and by the many different vectors of "change" that emerged in the articles. It seems that for our participants, change happens at several different levels—from the innermost personal transformations, to classroom teaching, to institutional and system-wide practices. A few authors chose to write primarily about MMSTEC's impact on their individual teaching philosophies. These papers are inward looking and focus on the authors' journeys of self-reflection as they challenged themselves to think about teaching in new ways. The greatest number of submissions describes classroom-level change. These contributions deal with the impact of changed teaching practices on student learning, attitudes, and/or the classroom environment. Some of these are research-based and provide quantitative data to illustrate their findings; others are more descriptive and use qualitative information to measure the impact of new teaching techniques. A few of the papers contain sample lesson ideas or assessment rubrics that could potentially be used in readers' own classes. In yet a third category, a couple of these papers are broader in scope and address the bigger picture of MMSTEC's efforts to improve mathematics and science education in Maine. These authors discuss the project's impact at the community level and beyond.

We decided to organize this monograph around the themes brought to us by the individual authors by grouping the papers in three sections: impact of personal change and teaching philosophy, impact of classroom-related change, and impact of organization-level change. In almost all cases, there are elements that blur the boundaries between these three categories, making it difficult to sort papers neatly. Any given submission may contain more than one major theme, or alternatively, one major and one minor theme.

In our attempt to ensure that our audience of readers is as diverse as our participants, we are disseminating this monograph to individuals representing all facets of mathematics and science education: teachers in grades 6-12; higher education faculty in mathematics, science, and education; pre-service students; administrators; policymakers; and others who have participated in MMSTEC activities over the past six years. In the end, we believe our work is a fair representation of the wide-ranging impact of the MMSTEC project, and trust you will find in it something of personal or professional value.

Amy Johnson
MMSTEC Research Analyst

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Introduction

In the mid-nineties, the National Science Foundation publication, *Shaping the Future* [1], set forth a national agenda for improving undergraduate education in the Science/Mathematics/Engineering/Technology (STEM) disciplines; and the Collaboratives for Excellence in Teacher Education (CETP) initiative, an NSF-sponsored program to improve the mathematics and science performance of K-16 students nationally, was instituted [2]. Since the program's inception, more than 35 CETP grants have been awarded. Because different states have different educational geographies, CETP-collaboratives have included different mixes of university campuses, K-12 districts, community colleges, and non-profit organizations.

In August 2000, the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC) was awarded a $4.1 million dollar five-year CETP grant. The Collaborative, now in its sixth year, consists of the University of Maine at Farmington (UMF), the University of Maine (UM), the University of Southern Maine (USM), the network of partner schools associated with each of the three campuses, and the Maine Mathematics and Science Alliance (MMSA), a non-profit group with close ties to the Maine Department of Education and an interest in improving mathematics and science education in Maine K-12 schools. Historically, these three campuses of the seven-campus University of Maine System (UMS) graduate approximately 80% of the teachers who complete a state-approved teacher preparation program in Maine.

Since the grant's inception, we have expanded the number of MMSTEC campuses to include University of Maine at Machias and University of Maine at Presque Isle. Thus, we now represent five of the six University of Maine System campuses with teacher education programs. Additionally, we have been awarded a total of $1,000,000 in NSF Teaching Scholars funds and Noyce Scholarships to help us recruit future teachers of mathematics and science.

Maine Schools 2004-2005

Maine, with a population of approximately 1.25 million people, has approximately 221,000 students enrolled in Maine schools, and 755 public and private schools in various grade span configurations. Because Maine is a rural state, many of these schools are small, with 16% of schools having less than 100 students, 21% of schools having between 100 and 199 students, and 47% having between 200 and 499 students [3]. The average expenditure per student is approximately $6,640 and the 33% of students are eligible for free lunches.

There are approximately 16,100 teachers in Maine; 42.5% of these hold a bachelor's degree, 10.9% have a bachelor's degree + 15 hours, 11.2% have a bachelor's + 30 hours, and 24.1% have a master's degree [4]. There are approximately 3,500 grades 6-12 mathematics and science teachers; about 10% resign or retire from their positions each year. One third of this 10% move to other Maine schools; the rest, or about 230 grades 6-12 mathematics and science teachers, either retire or leave the profession each year. From 1993-1998 Maine produced an average of approximately 43 total certified teachers per year in mathematics and sciences through graduation of qualified teachers exiting our collective teacher education programs. Thus, our net loss of mathematics and science teachers has been about 180 each year.

In addition to increasing the number of teachers, Maine must significantly improve the quality of our teacher education programs with respect to mathematics and science education [5]. One stark indicator of this need is that in 1998, the most recent year available while we were writing the grant proposal, 30% of Maine's 7-12 mathematics and science teachers taught in subjects outside their major compared to 27% nationally [6]. As in many states, teaching "out of area" is especially severe in the physical sciences.

Maine certification categories are grades K-8, 7-12, and K-12, and Maine is one of only 16 states with no explicit middle school certification category. Currently, in order to be certified K-8, one must complete 6 credit hours in science (not necessarily lab courses) and 6 credit hours of mathematics. In order to be certified to teach science 7-12 one can focus on either physical science certification or life

science certification; each of these currently require 36 credit hours of science with some required and some elected courses. To certify to teach 7-12 mathematics, one is also required to take 36 hours of specified courses. In September 2005, Maine's response to the No Child Left Behind legislation dictated changes in the certification requirements that led to 24 hours of required coursework and a standardized test in order to be considered "highly qualified" in each grade 7-12 subject taught.

University of Maine System: Fall 2005

Goal 1. Increase the number of highly qualified Maine grades 6-12 teachers.

Goal 2. Improve the curriculum offerings of teacher education programs on MMSTEC campuses.

The University of Maine (UM), with 11,222 students, has an undergraduate teacher certification program leading to a degree in education. For students interested in teaching middle school mathematics and science, UM offers a mathematics or science concentration consisting of 24 credit hours, twelve of which must be 200 level or higher. For those in a secondary track, 36 credit hours of science are required. UM also offers graduate Masters of Arts in Teaching (MAT) and Masters of Education (M.Ed.) programs leading to certification. The total number of students in the "pipeline" in 2004-2005 was 175, 110 in tracks leading to secondary certification, and 65 in the track leading to K-8 certification with concentrations in mathematics or science. Of the 175 students, 39 were in graduate programs.

The University of Maine at Farmington (UMF), with 2,420 students, has an undergraduate program similar to that at UM. Certified students graduate with a degree in education; those who are interested in teaching middle school mathematics or science take a concentration of 30 credit hours. In 2004-2005, the total number of students in the "pipeline" at Farmington was 219, with 116 in the secondary track and 103 in the K-8 track with intent to teach mathematics or science.

The University of Southern Maine (USM), with 11,007 students, has two K-8 undergraduate certification tracks: Teachers of Elementary and Middle Schools (TEAMS) at the Portland and Gorham campuses and Collaborative Learning and School Success (CLASS) at the Lewiston-Auburn campus. TEAMS and CLASS combined have approximately 100 students. USM also has a graduate fifth year K-12 certification program called the Extended Teacher Education Program (ETEP) with a yearly cohort of between 100 and 110 students. In 2004-2005, among the three programs, 26 were in the mathematics and science secondary track, while 7 were in the K-8 mathematics and science middle school track.

The two other MMSTEC campuses at Presque Isle (1,545 students) and Machias (1,313 students) are smaller, and are both situated in rural settings close to the Canadian border. They both have longstanding teacher education programs, with a tradition of preparing teachers for certification in both Maine and Canada.

MMSTEC Goals and Progress To Date

MMSTEC's primary focus and goal is to improve the mathematics and science learning of Maine's grades 6-12 children. The key to increased learning by children is to improve teaching, namely the content and pedagogical base of 6-12 teachers. Specific grant goals, with current progress toward these goals are:

1. Increase the number of highly qualified Maine grades 6-12 teachers.

In 1998-1999, when we were writing the MMSTEC grant proposal, there were 237 prospective mathematics and science teachers in the "pipeline" at the three founding MMSTEC campuses. Currently, there are 417, an increase of 70%. During that same time period, the number of graduated 7-12 Maine mathematics and science teachers has risen from 50 in 1998-1999 to 143 in 2004-2005. Much of this increase is associated with our advertising and public relations work through AXON Design Management (AXONDM), a Portland-based advertising and marketing firm, and with our internal recruitment of junior and senior mathematics and science majors at MMSTEC campuses. Externally, we advertise MMSTEC on radio, TV, in a sampling of the state's movie theaters, and through our website at http://www.educateME.info. Internally, we assign an MMSTEC advisor to each Mathematics and Science department; the advisor works with students interested in exploring the teaching profession, and makes sure that they are connected with appropriate faculty and staff in the colleges of education.

2. Improve the curriculum offerings of teacher education programs on MMSTEC campuses.

To date, there have been three significant and permanent curricular changes; each of these changes has removed a significant barrier to the increased "throughput" of teacher candidates. These changes are:

- Creation of an undergraduate Secondary Mathematics certification program at USM. The program began accepting students in the fall of 2003.
- Creation of a General Science major at USM to serve prospective middle school science teachers. The program began accepting students in fall of 2004.
- Creation of a masters degree certification track at UM to serve those with a baccalaureate degree in the sciences with an interest in teaching. This degree exists within the College of Arts and Sciences and is consonant with MMSTEC goals, but is not an MMSTEC product. Many MMSTEC faculty members participated in the creation of the degree, which was contemporary with the MMSTEC grant.

MMSTEC has also made a substantial positive impact on existing mathematics, science, science education, and mathematics courses at participating MMSTEC campuses. By April 2004, approximately 75 different courses spanning three campuses have either been influenced by MMSTEC, or are exemplary and consistent with MMSTEC values as put forth in the document Attributes of an Effective Classroom (AEC) (see page 10).

3. Increase the capacity of the UMaine System to provide quality mathematics and science education by adding three new tenure-track faculty positions with joint appointments spanning Colleges of Arts and Sciences and Colleges of Education.

Lack of adequate numbers of secondary mathematics and science education faculty within each teacher education program across the State has contributed to a lack of inter-campus interaction among this group, and a worsening insularity within campuses. Of the six University Maine System campuses with teacher education programs, there are 7.5 mathematics and 8 science tenured or tenure-track educators. It is next to impossible to expect one or two faculty members on each campus to teach their classes, do scholarship and service, and successfully attend to all the other issues related to quality mathematics and science education across a number of school sites. Because there is this lack of capacity, historically there has been little coordination among different programs within a campus, and among campuses with regard to common issues of mathematics and science education.

To provide addition human capital across the system during and after the duration of the grant, one major grant objective is to assure some institutionalization of grant efforts by hiring joint appointments, shared between Colleges of Arts and Sciences and Colleges of Education at each of the three original participating institutions. Three faculty members have been hired, one at each campus, and are in place. Each of the salaries and benefits of these three is paid from grant funds during the lifetime of the grant; each campus has committed, in writing, to pick up the salary and benefits of these hires when grant funds run out.

As joint appointments across two colleges, these hires are expected to provide increased capacity in mathematics and science education at each campus, and leadership in aligning the colleges to better serve mathematics and science education needs. The hires include two mathematicians/mathematics educators and one scientist/science educator. The appointments were made in September of 2000, 2001, and 2002. At each campus, lines of authority across the two colleges with respect to tenure and promotion decisions have been agreed upon. The respective Provosts have approved personnel policies and procedures addressing criteria for tenure and promotion. Peer Evaluation Committees have been established, and are equally populated with faculty from both colleges. The first joint hire at USM was tenured in March 2004.

4. Improve the content and pedagogical base of in-service teachers, pre-service teachers, and university faculty through focused professional development.

This goal, the major focus of most of this monograph, is detailed below in the sections on improving the content and pedagogic base of 6-16 teachers, pre-service teachers, and university faculty. The impact of MMSTEC professional development efforts can be read through their own stories that follow this section.

Goal 3. Increase the capacity of the UMaine System to provide quality mathematics and science education by adding three new tenure-track faculty positions with joint appointments spanning Colleges of Arts and Sciences and Colleges of Education.

Goal 4. Improve the content and pedagogical base of in-service teachers, pre-service teachers, and university faculty through focused professional development.

Improving the content and pedagogic base of 6-16 teachers, pre-service teachers, and University faculty

Pre-service teachers matriculated in teacher education programs whose mathematics and science education faculty are well-connected to Arts and Science mathematics and science faculty, and who also experience thoughtful teaching from Arts and Science faculty that is informed by both current educational and cognitive research are the key to improving the learning of all K-16 students.

Commentary

There are large cultural differences between faculties of Education and faculties of Arts and Sciences for many reasons. Colleges of education have been historically separate from colleges of arts and sciences. While faculty of Education have assumed responsibility for the education of teachers, most Arts and Science faculty have generally accepted little responsibility for this important function. Faculties of these two colleges read different scholarly literature and have different foci within their university context. Faculties of these two colleges hold different beliefs about classroom practice, and seldom talk to each other about those beliefs.

Given that content and process within any particular classroom are never independent of each other, and represent two different polarities along a spectrum of interaction, Arts and Science faculty have often focused mostly on content in their classes, while Education faculty have focused mostly on pedagogy. Thus, pre-service teachers receive contradictory messages about teaching from Arts and Sciences and Education faculty; some model their mathematics and science teaching on the classroom practices of mathematicians and scientists in Arts and Science, while others model their teaching on the classroom practices of Education faculty.

Since observing the teaching practices of their university instructors heavily influences pre-service teachers, the main leverage points for improving their performance as 6-12 teachers resides in the quality of the teacher education faculty and programs and the willingness of both Arts and Science and Education faculty to collaborate in the modeling of good teaching. Pre-service teachers matriculated in teacher education programs whose mathematics and science education faculty are well-connected to Arts and Science mathematics and science faculty, and who also experience thoughtful teaching from Arts and Science faculty that is informed by both current educational and cognitive research, are the key to improving the learning of all K-16 students [7].

Professional Development Opportunities

Improved learning by all 13-16 mathematics, science, and education majors, along with appropriate pedagogic modeling by Arts and Science faculty, are implicit grant goals since many science majors eventually enter a fifth year certification program or a masters degree program leading to certification. The content and pedagogic base of pre-service teachers will improve through focused professional development of faculty with whom they come in contact through teacher certification programs, including faculty in both colleges of education and colleges of arts and sciences. Professional development for Arts and Science faculty must focus on the questions "How do students learn mathematics and science?" and "What pedagogic practices assure maximum student learning?" Professional development of Education faculty must include teaming with Arts and Science faculty around content clusters suggested by national standards.

To that end, MMSTEC offered focused and thoughtful professional development based on current research about student learning for 6-12 teachers, pre-service teachers and university faculty. MMSTEC professional development opportunities included weeklong summer academies (SA), annual midyear conferences (MYC) held Friday evening and Saturday, and learning communities that have emerged both within a campus and across campuses.

Summer Academies and Midyear Conferences

Both the summer academies and the midyear conferences are designed for in-service teachers, pre-service teachers, and university faculty. We work in heterogeneous groups that include representatives from each of these three categories. Appendix I lists the agenda and presenters of our summer academies and midyear conferences. MMSTEC chose to focus the first two midyear conferences and the first summer academy on the latest research on how students learn mathematics and science, and what that implies for our teaching. The second summer academy focused on the role of research in science and mathematics educational reform. The third midyear conference focused on what Maine teachers and university faculty were doing differently in the classroom, based upon the MMSTEC professional development of the previous two years. Summer academies three and four provided examples of classroom practices, curriculum, and technology that

promised to make a significant difference in student learning, while the midyear conference four focused on assessment of student learning and how we know that we are positively impacting student learning. Thus, we have moved from research on student learning to implications for our teaching based upon this research, to dissemination of promising classroom and curricular practices that support increased student learning, to assessment of student learning.

Attendance at Summer Academies and Midyear Conferences is show in the table below.

Summer Academy	*Attendance*	*Midyear Conference*	*Attendance*
2001	61	2001	72
2002	75	2002	104
2003	92	2003	112
2004	116	2004	143

As the grant has unfolded in time, the number of attendees at these events has steadily risen, as has the percentage of 6-12 teachers attending these events. MMSTEC believes that we have provided useful professional development, and have made a significant impact on Maine faculty and teachers. Data supporting this statement is available in the MMSTEC Evaluation Report of years 1, 2, 3 and 4. For instance, in grant year two, 84.6% of summer academy respondents reported that they had made changes to their instructional practices since the first academy. In addition, over a three-year period, more than 90% of summer academy respondents rated the quality of the academy offerings as excellent or good, and over 90% were greatly interested in improving learning in their classroom. Similar results can be found in evaluations of the midyear conference [8].

MMSTEC Learning Communities

One effective mechanism for providing professional development for faculties from both colleges occurs through the formation of MMSTEC learning communities in which faculty discuss effective classroom teaching and appropriate content from very different perspectives. Over time, as trust develops, faculty start to listen to one another and classroom practice combining content and effective pedagogy begins to change. This change takes time; the Arizona CETP's evaluation report estimates that true reform of classroom practice takes between four and seven years [9].

MMSTEC took certain actions to build effective learning communities, narrow the cultural gap between Arts and Sciences and Education faculty, introduce teaching changes in individual classrooms, and strengthen the ties between these two faculties. First, the six grant co-PIs are equally split among Education and Arts and Sciences. Second, each campus has a Local Leadership Team (LLT) whose task it is to translate MMSTEC overall goals to local action. These groups include faculty from Arts and Science and Education, 6-12 teachers, and pre-service teachers.

At each campus, the LLT brings together groups of faculty from Education and Arts and Sciences, 6-12 teachers, and pre-service teachers to discuss the difference in perspective among the three groups and to share classroom practices and philosophies. By the grant's end, MMSTEC professional development opportunities will have influenced all mathematics and science education faculty and 50% of the Arts and Science mathematics and science faculty at USM. At UMF, all of the mathematics and science educators and 70% of the mathematics and science faculty will be influenced, while at UM, the figures are 75% of the education faculty and 25% of the mathematics and science faculty.

One effective mechanism for providing professional development for faculties from both colleges occurs through the formation of MMSTEC learning communities in which faculty discuss effective classroom teaching and appropriate content from very different perspectives.

The groups formed vary from campus to campus, but all are a form of a learning community, and comprised of members with very different backgrounds and viewpoints. The groups generally meet once a month and can take the following forms:

1. Cross-Tier Teaching Team (CTTTs): These disciplinary teams are comprised of Arts and Science and Education faculty, pre-service teachers, and 6-12 mathematics and science teachers. They meet once a month and all in the group help determine the topics addressed. These can be content or pedagogically focused, or a mixture of both. There are three such teams on the UM campus, one each focused on Mathematics, Technology, and Environmental Education.

2. Geographic Groups: These teams are comprised of the same groups as the CTTTs, and have met at both USM and Farmington. The groups morph between discipline-based and a more amorphous blend (science and mathematics splits), and focus on either general issues in mathematics and science education or as sounding boards for university faculty and classroom teachers contemplating changed classroom practices.

The focus of all pedagogical changes is increased student engagement in rich content.

3. Local Leadership Teams (LLTs): At USM, the Local Leadership Team met once a month to discuss what was needed to advance the MMSTEC agenda at USM, and to formally discuss changes in teaching practice by individual members of the group. The latter activity provides the most faculty enthusiasm and fun than any other MMSTEC activity.

In each of these three groups, discussions have been focused on increasing student learning in the classroom. We ask MMSTEC participants to:

- Use at least one new teaching technique each semester,
- Observe whether this technique leads to an increase, a decrease, or no change in student learning,
- Share with the group how they determined whether there was a change in student learning,
- Fill out a faculty/teacher activity report each year explaining their pedagogical change, and what they have done to measure any change,
- Provide classroom artifacts to the larger group, and
- Be available for a classroom observation by trained observers.

This format has led to a tremendous amount of discussion about classroom practice, teaching philosophies, and explicit and implicit educational values. It has also led to the creation of the AEC which we use to align our evaluation plan with our vision of the grant, as well as to publicize the pedagogical goals of the grant to the larger educational community. Evaluation data point to diminished barriers among Education faculty, Arts and Science faculty, and teachers [10].

Strengthened Pedagogic and Content Base of Grades 6-16 Educators

MMSTEC professional development opportunities have led to changes in classroom practices. With regard to new pedagogic techniques, the following are being used in Arts and Sciences and Education faculty classrooms:

- Animations to help students understand
- Peer-Led Team Learning groups
- Informing students of current science news that matches a particular course
- "One minute papers" to gather formative assessment data associated with the day's class
- Distribution of instructor class notes at the beginning of each book chapter
- Empowering students to choose their own form of assessment
- Giving students some control about what is covered in the course, and the sequence of such coverage
- Asking students to write a one-page paper about themselves between the first and the second class of the semester. The instructor also completes the same task. The papers are exchanged. (This idea came from a graduated NSF Scholar from UM.)
- In a sophomore level chemistry class, keying the "lecture" portion of the class to the lab portion of the class (two different instructors).
- Group work (in-class) on various problems, and presentation of the results by a group representative.
- Substantial formative assessment.
- Incorporation of appropriate technology such as PASCO and Vernier probes, and Geometer's Sketch Pad
- Administration of the View Of Nature attitudinal survey to gauge the impact of inquiry-based teaching
- Letting student questions guide the content
- Identification and work with student misconceptions
- "Muddiest point" assessment

The focus of all pedagogical changes is increased student engagement in rich content. Appendix II lists pedagogic techniques by course so the reader can see what is happening in individual courses. Summed over 75 courses on three different campuses, the cumulative change in teaching practices associated with the core group of MMSTEC faculty is impressive. Our hope is that this core group will act as an effective change agent for the improvement of mathematics and science teaching and an increase in student learning in the University of Maine System.

Our evaluation plan uses data from student class surveys, faculty class surveys, classroom observation by trained observers (CETP Core Observation Protocol

Summary

(COP) developed by The Center for Applied Research and Educational Improvement at the University of Minnesota), and qualitative data gathered from university faculty and graduated MMSTEC teachers (classroom activity reports) to gauge the extent of grant impact. We have collected baseline data in grant years one and two, and additional data in years three, four and five; triangulation of data from these three different data sources suggests that our efforts have had a positive impact on course reform. The database is still too small to make substantive conclusions, but we think we are on the right track regarding our collaboration and changes in classroom practices. That MMSTEC faculty are allowing, and in some cases welcoming, classroom observations is a remarkable change in attitude given the historical resistance of university faculty to peer classroom observation, and the isolation in which many of us have traditionally taught.

MMSTEC's work over the sixth, and last year of the grant will focus on classroom observation of university mathematics, science and education classes, and measurement of student gains in knowledge. If we can document changes in classroom behavior that lead to increased student gains in knowledge, we will have strengthened the mathematics and science education of both pre-service teachers and Arts and Science majors, narrowed the cultural gap between Education and Arts and Science faculty, and progressed a good ways toward becoming a more cohesive university community.

After this extensive introduction to inform the reader of the full scope of MMSTEC activities and goals, the heart of this publication is a collection of papers from Maine teachers, university professors, and pre-service teachers who have made changes in the way they teach mathematics and science. Their work on classroom practice, reflecting the latest educational findings about student learning, is a testimony to their dedication as teachers. As the MMSTEC Project Director, I honor their work, and present it to you as stories of transformation. The authors of these stories are at very different mile-markers in their journeys, and as all of us know, these journeys never really end. If we are generally moving in the right direction, it is the journey that is important, not the final destination. The hope of increased understanding in mathematics and science, and indeed for all fields is an attainable and important goal. Hopefully, these stories will both inform and inspire, and MMSTEC faculty will continue to act as a positive change agents across the state of Maine.

That MMSTEC faculty are allowing, and in some cases welcoming, classroom observations is a remarkable change in attitude given the historical resistance of university faculty to peer classroom observation, and the isolation in which many of us have traditionally taught.

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APPENDIX I

Summary Academy (SA) and Midyear Conference (MYC) Topics and Presenters

MYC 2001

What does current research tell us about how students learn Mathematics and Science, and what are the implications of such findings for our teaching?

Lillian McDermott and Paula Herron, University of Washington

SA 2001

What does current research tell us about how students learn Mathematics and Science, and what are the implications of such findings for our teaching?

José Mestre, University of Massachusetts, Amherst

Diane Ebert-May, Michigan State University

Roger Howe, Yale University

MYC 2002

What does current research tell us about how students learn Mathematics and Science, and what are the implications of such findings for our teaching?

Joan Ferrini-Munday, Michigan State University

Richard Yuritich, University of Massachusetts

SA 2002

The Role of Research in Science and Mathematics Education Reform

Gordon Uno, University of Oklahoma

Joe Reddish, University of Maryland

MYC 2003

What are Maine teachers/faculty doing differently in the classroom that makes a difference in student learning?

MMSTEC faculty/teachers

SA 2003

Dissemination of effective teaching practices

Strand 1: WRITE ON! (Run by OCEPT; Diane Smith and Elaine Cole)

Strand 2: Data Analysis and Statistics, TI

Strand 3: Connecting Physics and Mathematics, TI

Strand 4: K-8 Mathematics Summit

Strand 5: Pasco and Vernier Probes

Strand 6: Future Mathematics/Science Clusters as possible Masters Degree Options.

MYC 2004

How can we know/assess that we are increasing student learning

Maine teachers and faculty

Jill Rosenblum, Maine Mathematics and Science Alliance Assessment Specialist

SA 2004

Dissemination of effective teaching practices/assessment

Strand 1: WRITE ON! OCEPT; *Diane Smith and Elaine Cole*

Strand 2: Geometer's Sketch Pad *Todd Shockey UM*

Strand 3: FAST *Don Young, U. Hawaii, and Richard Beer, Kennebunk High School*

Strand 4: Assessment *Julie Libarkin, Ohio University*

Strand 5: Course Development for Middle School Teachers *Nancy Austin, USM and Chuck Kim, UMM*

MYC 2005

How can we focus our past work to extend MMSTECs impact beyond its scheduled end-date?

APPENDIX II

Some MMSTEC Classroom Changes by Course

1. *Department* Chemistry
   Course Intro Chemistry for science majors
   Size 200
   Technique Total student-student interaction and active learning
   When Fall 2002

2. *Department* Teacher Education
   Course Mathematics Methods for grades K-8
   Size 2 sections of 15
   Technique Inclusion of research papers, summaries, and videos on the way children think, learn, and construct knowledge

3. *Department* Chemistry and Physics
   Course Intro Chemistry for science majors
   Size 200
   Technique Peer-Led Team Learning (PLTL)
   When Spring 2003, Summer 2003, and Fall 2003

4. *Department* Chemistry
   Course Chemistry for the Health Sciences (Nursing)
   Size 80
   Technique Measurement in gains in student learning associated with student-student in-class interaction, and other active learning pedagogical measures.
   When Spring 2003

5. *Department* Biology
   Course 100-level Biology Foundations
   Size 60
   Technique Student-student group work, use of Diagnostic Learning Log to identify misconceptions, use of a test evaluation to promote student reflection
   When Fall 2002

6. *Department* Mathematics
   Course Geometry for pre-service teachers
   Size 20
   Technique Student group interaction, filming of students solving problems as one form of assessment
   When Fall 2004

7. *Department* Biology
   Course Intro Biology for majors
   Size 90
   Technique More inquiry-based approach to Biology, increased instructor-student interaction, more variation of in-class activities, change class format from twice a week to three times per week
   When Spring 2003

Attributes of an Effective Classroom

1. All students are engaged in learning.

Instructors create a learning environment that includes:

- Respect for diversity of ideas and people by valuing and challenging all learners. Examples of this include:
- Teachers select content, and adapt and design curricula to meet the interests, knowledge, understanding, abilities and experience of student.
- Teachers select instruction and assessment strategies that support the development of student understanding and nurture a community of learners.
- Teacher's course activities encourage student reflection on their learning.
- Connecting content to prior knowledge.
- The connections among content and real world phenomena are explored and valued.
- Setting intellectual expectations that challenge all learners.

2. Classes are communities of learners.

Both instructors and students:

- Respect each other.
- Take responsibility for their learning.
- Actively participate in class activities.
- Work collaboratively with colleagues and peers.
- Communicate their ideas to each other in a variety of ways.

Instructors:

- Act mostly as resource persons working to enhance and support student investigation.
- Effectively mediate the relationship between the subject matter and the students. Effective mediation means that there is a balance between "teacher as listener", "teacher as guide", and "teacher as provider of direct instruction."

** These five major attributes will be true for 6-16 classrooms. We realize that in some university upper-level mathematics and science courses, the thread between real-world application and theory becomes quite thin, and at times, apparently invisible.*

3. The management and monitoring of student learning is frequent and purposeful.

Students:

- Tell teachers what they think they need to learn.
- Reflect upon and assess their learning.

Instructors:

- Assess students' prior knowledge using a variety of assessment techniques.
- Identify student misconceptions and alternative frameworks of thought.
- Revise instructional methods to reflect students' prior knowledge and conceptual frameworks.
- Frequently assess students' progress toward clearly stated goals.

4. The class focuses on fundamental concepts in the content area and the interrelationship among these concepts.

Instructors:

- Have a deep understanding of fundamental concepts in her/his content areas.
- Are effective in teaching these concepts to students. Effectiveness includes:
- Being able to approach/explain a content area in several different ways.
- Knowing the effective balance between instructor/student explanation and further student exploration.

5. Pedagogic procedures specific to mathematics and science are emphasized.

Students:

- Use an inquiry-based approach to learning.
- Use elements of abstraction when appropriate.
- Use a variety of means to represent phenomena.
- Make predictions/hypotheses and explore ways of testing them (science), or make conjectures and explore ways to prove or disprove them (mathematics).
- Analyze and interpret data.

Journeys of Personal Change

Soul Versus Role in a Dual Appointment Position

Grace Eason
Assistant Professor, Science/Science Education
University of Maine, Farmington
geason@maine.edu

The principal investigators of the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC) grant envisioned three individuals in dual appointment roles. Two of those appointments were in mathematics and mathematics education; the third was in science and science education. This paper describes how the author, an assistant professor in science and science education, was challenged to lessen the cultural gap between the College of Arts and Sciences and the College of Education, and in attempting to do so, discovered how disciplinary division could also create a division between one's soul as a teacher and one's role as a teacher. When we begin to establish territories in our disciplines then the division becomes more pronounced over time, until eventually, we assume that we no longer share a common vision; is there a way for us to consider our commonalities rather than our differences? If so, how do we begin?

Introduction

When I was a graduate student at the Florida Institute of Technology, I had the unique opportunity to work with a group of scientists who received a NASA Earth Systems Science Education grant to develop and team-teach an integrated introductory science course for science majors. Seven scientists, representing a variety of disciplines including biology, geology, physics, oceanography and environmental science, set out to provide first-year science majors with a holistic way to view the Earth. The goal was to develop a "Whole Earth" course that students would take during their freshman year and then, in their senior year, return for a capstone experience, bringing their expertise from their individual majors to contemplate global system issues such as global climate change. As a graduate student in environmental science education, my role was to provide guidance in course organization and implementation. Discussions revolved around specific course objectives, pedagogy, technology integration, and assessment.

The differences in our disciplinary training were evident from the beginning, making it difficult at times for us to communicate. Many of the scientists I worked with believed educators were more concerned with pedagogy than content. And I couldn't help but believe that some scientists were more concerned with content at the expense of pedagogy. Zeidler describes this difference as almost feudal, with "different paradigms...deeply steeped in traditions that stand in contrast to one another" (Zeidler, 2002). Faced with this dichotomy, I realized I needed to learn how to speak the language of both science and education.

After gaining some experience working with these two different cultures, it was no surprise that I found myself in a dual appointment position in both science and science education shortly after graduation. The position was advertised as part of an NSF grant, known as the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC). The goals of the grant were to recruit, support, and retain mathematics and science teachers across the state of Maine. Three Maine universities were involved. Because the principal investigators wanted to lessen the cultural gap between the Colleges of Arts and Sciences and the Colleges of Education at all three participating institutions, they envisioned three individuals in dual appointment roles. Two of those appointments were in mathematics and mathematics education; the third was in science and science education.

Because of my experiences in graduate school, I had first-hand experience working within the two

paradigms of science and science education. So when I was interviewed and asked what I would do to help bridge the communication gap between these two colleges, I remember stating that each discipline speaks a different language. By recognizing that, we could begin to try and understand each other by first listening to what the other had to say. It was clear from the question that, in addition to being a teacher and scholar I was expected to become a "peacemaker." My path was there before me. All I had to do was take the first steps.

I often feel that I am constantly living a divided life; in essence, there are two sides that exist within me.

Being Mindful of the Cultural Gap

One of the first steps I took toward gaining a better understanding of this "gap" involved learning more about the art of teaching by listening to my colleagues in both science and education. First, I teach introductory biology and environmental science to undergraduate non-science majors. I believe my responsibilities to them are to inspire and fill them with the same passion for the subject that I have by making it interesting, relevant, and applicable to their daily lives. Second, I teach undergraduate middle/secondary science pre-service teachers. It is here that I must share my passion for the art of teaching science and inspire and guide them to find their own inner natures as teachers.

Since pre-service teachers take both science and education courses, territorial struggles begin to ensue, particularly when pre-service teachers are required to do a practicum and student teaching field experience. It is difficult for them to fit in all of their science and education courses and graduate within four years. Some scientists have the premise that content is what makes good teachers, and that courses in pedagogy and field experiences are really not necessary. After all, they did not receive a degree in education and some of them have been teaching for 20 years. There is no doubt, content is critical, after all, how can we teach well if we do not know our discipline deeply. Yet, there are elements to teaching and mentoring that are essential for new teachers to experience if we want them to remain in teaching. Zeidler (2002) provides additional insight into this conflict by saying, "Colleges of Arts and Sciences may produce successful scientists in the time honored tradition of social behaviorialism, but the overarching instructional methodologies employed within that tradition are clearly incompatible with those employed within the experientialist tradition and advocated in science education reform. One can argue that one tradition is 'right' and the other 'wrong,' but the more relevant question to be raised when collaborative ventures are undertaken is whose needs should be served? (p. 36)"

This division between instructional methodologies can be overwhelming for someone who is trying to work with both sides. I often feel that I am constantly living a divided life; in essence, there are two sides that exist within me. On one side there is my soul as a teacher; it is in this place that my values, beliefs, and my true inner nature lay. On the other side is my role as a teacher and peacemaker in this dual position; it is in this place that my identity, my image, and my interactive nature come out to help me in my work. In between both sides is a wall that has developed where often times I find myself struggling to maintain my soul as a teacher. Once we begin to establish territories in our disciplines then the division becomes more pronounced over time, until eventually, we assume that we no longer share a common vision. Is there a way for us to consider our commonalities rather than our differences? If so, how do we begin?

The issue of finding time to research the many questions that have emerged while serving in this position has been a huge challenge. Our institution wants faculty to be adept in all four areas of teaching, scholarship, university service, and community service. We are a small rural institution and faculty are heavily involved in all of these areas. Junior faculty must be sure to strengthen their teaching, yet remain very active in their research and scholarly publication. Attempting to find a balance among these areas has been difficult.

Boyer (1990) once wrote, "move beyond the tired old 'teaching versus research' debate and give the familiar and honorable term 'scholarship' a broader,

more capacious meaning, one that includes four distinct but interrelated dimensions: discovery, integration, application, and teaching." But, how can an untenured faculty member who is reviewed by her peers, deans, provost, president and board of trustees prove her worth for tenure? Clearly, the current model in higher academe insists on research and publication as the primary focus. I do find Boyer's model ideal, yet I am struggling with his proposed integration, for it seems to be incompatible with the demands of higher academe. Nevertheless, this dual appointment has allowed me to work in several areas (science, education, and science education) that provide me with some research flexibility.

Evolution of the Peacemaker

...we ask our students to reflect about their learning by asking them to critically analyze how they perceive themselves as learners in an academic setting, but rarely do we give ourselves that opportunity.

I have found that my current research with college faculty has been extremely rewarding even though it took me quite a while to establish a trusting relationship with my colleagues in science and in education. Parker Palmer describes a situation that I am very familiar with, particularly after working with the MMSTEC grant. Palmer (1998) states, "I will never forget one professor who, moments before I was to start a workshop on teaching, unloaded years of pent-up workshop animus on me: 'I am an organic chemist. Are you going to spend the next 2 days telling me that I am supposed to teach organic chemistry through role playing?'"

Good communication and a trusting relationship is, therefore, extremely important. Much of my time is spent visiting with faculty members on a one-to-one basis and discussing various issues with them. The issues have varied considerably and the discussions have evolved around science teaching, teaching in general, educational philosophies, or even university service. Although time consuming, these interactions have allowed me to re-examine many areas of my own teaching and scholarship that I have not considered previously. In addition to teaching my classes, conducting research, serving as an NSF grant coordinator and sitting on numerous committees for both departments, I am attempting to establish a trusting relationship with faculty. I do this not only for my research but to facilitate a greater understanding and appreciation for the differences in our scholarly training and to build a bridge for communication. I believe it is through these interactions that we can achieve Boyers "integration."

There have been times, however, when some of the interactions have not been very positive. One day, while walking through the hallway, I was stopped by two of my natural science colleagues, and one of them asked me what my title was. Before allowing me to answer he asked, "Shall I call you a pseudo-scientist?" Initially, I was stunned, but shortly afterward I returned with my own question: "If you are defining a scientist as a person who has his or her doctoral degree in a particular science discipline, then yes, you may call me a pseudo-scientist." In my thoughts I also wanted to add, "Shall I call you a pseudo-educator because you do not have your doctoral degree in science education?" Some may perceive this interaction as negative, but I considered it a learning opportunity for my colleagues and me. The question here was not what was said, but why it was said? It was at this point that I realized that perhaps one of the main differences between the fields of science and education was in the way scholarly research was conducted. From that exchange, my science colleagues explained to me that sometimes the "models" that educators employ do not seem to be grounded in supporting data. I described the various issues educators must contend with when conducting research with human subjects and I began to share science education research with them.

If historically at one time, humankind was fascinated about learning and gaining knowledge in all areas and learning from each other, how and why have things become so different? As teachers, do we not have the same goal in mind, to do what is right for our students? Often times, conversations with both science and education colleagues would occur in a hallway on the way to the lounge, the copy machine, or right before some meeting. Sometimes, these conversations would involve "intelligence information" regarding what the other side is "doing". Mainly, the conversations focus around advising students, program changes, administrative

However, good teaching is embedded within an instructor's ability to reflect on their own teaching practice and in doing so, engage their students with the subject about which they themselves are passionate.

issues, and the general education curriculum. But rarely do the conversations involve our teaching. We all strive to create a supportive community of learning for our students and we ask our students to reflect about their learning by asking them to critically analyze how they perceive themselves as learners in an academic setting, but rarely do we give ourselves that opportunity. In essence, isn't our ultimate goal the search for truth no matter what discipline we are from? But I believe that how we search for truth will vary depending on what we are looking for. Parker Palmer once wrote:

- "The question we most commonly ask is the 'what' question—what subjects shall we teach?
- When the conversation goes a bit deeper, we ask the 'how' question—what methods and techniques are required to teach well?
- Occasionally, when it goes deeper still, we ask the 'why' question—for what purpose and to what ends do we teach?
- But, seldom, if ever, do we ask the 'who' question—'who' is the self that teaches? How does the quality of my selfhood form—or deform—the way I relate to my students, my subject, my colleagues, my world? How can educational institutions sustain and deepen the selfhood from which good teaching comes? (Palmer, 1998)"

Palmer's description of the levels of teaching, are truly worthy of consideration, for they invoke pause, silence, and reflection—elements we rarely make time for because, in reality, how can we consider "teaching" as a scholarly pursuit? Often times, the act of teaching is not considered scholarly; it is something that instructors automatically "just do". However, good teaching is embedded within an instructor's ability to reflect on their own teaching practice and in doing so, engage their students with the subject about which they themselves are passionate. Those instructors who elect to be engaged in this process must, of course, know their subject well and continually strive to stay current in their field. According to Hutchings (2000) "the scholarship of teaching and learning is deeply embedded in the discipline; its questions arise from the character of the field and what it means to know it deeply." However, in addition to knowing the content there is also the dynamic pedagogical knowledge that accompanies the practice of good teaching to enable us to communicate our subject to our students effectively so that they too can be engaged with the material and understand it. According to Boyer (1990) "pedagogical procedures must be carefully planned, continually examined, and relate directly to the subject taught. Educator Parker Palmer strikes precisely the right note when he says, "knowing and learning are communal acts." The other component to add to this form of scholarship is to stress that faculty are also learners and that good teaching will emerge when instructors take the time to meaningfully reflect on their own teaching.

This form of meaningful reflection is difficult to distinguish from the mere act of teaching each day and is even more difficult to tease out when we engage in research about our teaching. Hutchings (2000) provides additional insight by saying "it is an aspect of practice. In contrast to research done by a 'third party' examining the practice of others, this is work if you will, in the 'first person,' undertaken by faculty looking at their own practice (and sometimes the practice of colleagues with whom they teach or share curricular responsibility). Indeed, the scholarship of teaching is hard to distinguish from teaching itself. It's not just about one's teaching; it is an element within teaching, hard to separate out." Is part of this cultural gap due to the differences in research between the two disciplines of science and science education? Or is it due to the differences in our teaching? Or is it both? These questions continue to linger as I attempt to make sense of this discord between these two disciplines. If we differ in our methods based on our disciplinary training for the search for truth what does that mean for a science educator who has to straddle both science and education? How do we begin to trust each other?

A Sense of Community

Trust is a simple yet extremely profound word that over time can be taken for granted. The teaching profession as a whole can be extremely solitary in nature, where we have a tendency to stay closed off in our disciplinary silos. As time passes we form walls around ourselves, shielding ourselves from our colleagues and our students. We begin to protect "our domain" and no longer allow ourselves to become vulnerable by asking a colleague to observe us in our practice, let alone take the time to establish a space for meaningful discussion about our teaching. Parker Palmer (1998) describes this phenomenon very well. "Academic institutions offer myriad ways to protect ourselves from the threat of a live encounter. To avoid a live encounter with teachers, students can hide behind their notebooks and their silence. To avoid a live encounter with students, teachers can hide behind their podiums, their credentials, and their power. To avoid a live encounter with one another, faculty can hide behind their academic specialties."

One of my solutions to this dilemma has been to take the time to visit with both science and education faculty individually. Occasionally I would ask for advice regarding my teaching or advising of students; other times I have just maintained contact, hoping that we can begin to trust each other. After all, how can we ask faculty to observe each other teaching and establish an element of trust, if we don't even know who "we" are? We strive to create a community of learning for our students. Can we not also strive to create a community of learning and teaching for ourselves regardless of our disciplinary training? After working on this grant I have had a glimpse of this type of community, where scientists and educators from across the state of Maine convene together to learn and support each other.

One example of this type of community experience comes from a writing retreat called Write-On, where, in fact, I began writing this paper. Scientists, science educators, mathematicians, and mathematics educators are provided time, quiet space, food, good company, a writing coach (i.e. "whip cracker") and a developmental editor. A critical component to this retreat was that we were given permission to take time for reflection and for writing, something that we often do not give ourselves during our day-to-day lives. In this setting even though we were alone to do our work, we were together because we took the time to convene as a group, set our goals together and support each other. This forum provided us with the opportunity to share our work by reading each other's papers, which fostered discussions about our teaching. In the evenings when we were not writing, the retreat provided us with the time to share our stories of who we were.

I have had the privilege of experiencing numerous encounters like these while working on this grant and everyone that I have asked has said that one of the greatest gifts they received from participating in MMSTEC is this interaction with each other. Imagine the types of rich discussions that have occurred when a group consisting of scientists, science educators, expert teachers and novice teachers are provided with an opportunity to sit around a table and talk about their teaching. It is at these very moments where we begin to feel enlivened about our work. Palmer (1998) writes, "Knowing is always communal. Through knowing, we make community with "the unavailable other," with realities that would elude us without the connective tissue of knowledge. Knowing is a human way to seek relationship, to have encounters and exchanges that will alter us."

We strive to create a community of learning for our students. Can we not also strive to create a community of learning and teaching for ourselves regardless of our disciplinary training?

An Invitation for Wholeness

These experiences made me realize that regardless of our disciplinary background when we focus on our commonalities, in this case our passion for teaching, instead of our differences, trust begins to grow. This is just one steppingstone on the path toward alleviating this cultural gap, but it is a very important step in understanding each other. In my own work I have seen many connections that have strengthened. For example, in working with our regional teachers and after providing the space they needed for good discussion, they have asked that we continue this work even though the grant has finished. Many teachers indicated that our dinners and workshops were the only time that they get to interact with each other in a meaningful way.

These experiences made me realize that regardless of our disciplinary background when we focus on our commonalities, in this case our passion for teaching, instead of our differences, trust begins to grow.

As far as working within both departments at my university, progress is slow, and yet, what I have started to notice is that we are all sharing our ideas more freely with each other. We have begun to discuss the readings we have chosen for our classes, how we assess our students, and what it is we want them to know once they finish our courses. Progress has been slow because the academic culture does not always lend itself to "a shared vision of intellectual and social possibilities" (Boyer, 1990). Faculty members become isolated from one another and administrative priorities take precedence at faculty meetings instead of providing time for faculty to discuss their teaching. This is a challenging issue, however, one that can be overcome as long as the level of trust among colleagues is maintained and encouraged, and in my case, that my colleagues from both departments trust me. Palmer (1998) describes that we are trained to "think the world apart," dissecting it into either-ors, but we need to learn to "think the world together," embracing opposites and appreciating paradoxes." If scientists and educators who are passionate about their teaching were to focus on this one shared vision and if they could begin to discuss this vision with each other, it would be like a pebble being dropped into a large lake, at first the ripples are quite small, and then, left undisturbed the ripples expand across the surface of the entire lake until every part of that body of water has been affected by that one pebble.

***Grace Eason** is an assistant professor of science and science education at the University of Maine at Farmington. She teaches introductory environmental science and science education methods for future science teachers. For her environmental science students, she believes her responsibilities are to inspire them by making environmental science interesting, relevant, and applicable to their daily lives. In teaching her pre-service teachers, she believes that she must share her passion for the art of teaching science and inspire and guide them to find their own inner natures as teachers.*

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Cultivating Opportunities for Student Success in Secondary School Science

Chuck Kim

Assistant Professor of Science Education
University of Maine at Machias
ckim@maine.edu

The instructional strategies and learning activities used to educate quality secondary school science teachers should model the strategies teacher candidates will use in their classes. The author describes changes to his instruction that help pre-service science teachers develop an understanding of the role of inquiry to motivate students' active learning and concept acquisition as well as to appreciate mathematics as an effective inquiry tool. He frames this discussion with insights from his own high school teaching experiences, an examination of the components of inquiry, and specific examples from his university level methods classroom.

Science Education From My Experience

After growing up in Korea and graduating from Korea University in 1961 with a B.S. degree in physics, I came to the United States in 1968 and taught science at Green Hills High School (pseudonym), New Jersey from 1969 until 2001. During 31 years of teaching at Green Hills High School, my greatest challenge was understanding why so many students did not work hard, why so many students failed each year, why so much tax money was spent on summer school for students who had failed, why so many ability groups (tracks) existed, and why so many students did not even try to advance to college.

In 1993, when I finished my dissertation, I began to think about major educational issues more seriously and asked myself, "What is a good high school?" The high schools I remembered in South Korea were not necessarily "good schools." Their goal was simply to prepare students for college thoroughly, and nothing other than content knowledge was important. However, some aspects of South Korean schools were quite effective. These schools exclusively used heterogeneous grouping in which everyone was expected to succeed and to complete fours years of mathematics and science. Schools offered no remedial mathematics classes. Most students succeeded and applied to attend colleges, although only about half of the graduates could advance to colleges.

After 32 years of teaching at Green Hills High School, I was hired as an assistant professor of science education at the University of Maine at Machias (UMM) in 2001. I began to participate in the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC) project in 2002 and to work with faculty from University of Southern Maine, University of Maine, University of Maine Farmington, and University of Maine Presque Isle. Since then I have attended summer academies, annual conferences, and UM Cross Tier Teaching Team (CTTT) monthly dinner meetings. Working with other educators, University of Maine System faculty, pre-service teachers, and in-service teachers gave me further insights into our educational beliefs about science and mathematics education.

I believe three critical educational issues negatively impact student success in secondary school science in Maine—failure in attaining standards, ability grouping, and inadequate teaching methods. Regarding failure in attaining standards, too many students are doing poorly in science. For example, one county in Maine has eight public high schools and more than 90% of 11th grade students from all eight schools did not meet the science education standards in the Maine Educational Assessment (MEA) in 2002. Regarding ability

grouping, many high schools use ability grouping and many students are classified as special education students. These special education students are often removed from regular classes and placed in remedial classes because they disrupt the regular classes, and therefore do not have to take some of the most challenging core high school courses such as Algebra, Geometry, and Physical Science. This ability grouping is isolating the learners who struggle and letting them fail to meet the standards.

If we transform our students into active learners through meaningful activities and if we make sure every student succeeds in every class, then our students can enjoy learning and meet the science education standards.

Regarding the third issue, teaching methods, I have found through my consultation for local schools, supervision of student teachers and association with other high school teachers at workshops and conferences that many schools operate without visions and curricula, and therefore some teachers teach any content without constraints. Furthermore, some teachers use the same techniques of teaching and learning they learned from their own high school experiences. These techniques include lecture, discussion, reading, and homework from textbooks and true/false and multiple-choice questions. I do not see enough of the interesting and meaningful laboratory activities that are needed to turn students into active learners.

Our students fail because we do not have an adequate educational system. We like to blame student failure on families or student "inability to learn," but its about time that we as educators reflect on what we have been doing and what we can do to change the tide of failure into a tide of success. We need to believe in our students' potential to learn and grow. If we do not believe in student ability, but continue to maintain low expectations and tolerate mediocre learning from students in remedial courses, our chance to achieve education standards is very low. However, if we have high expectations for all of our students, if we align our curriculum content to the standards, and if we change our ways of teaching, then our students will learn better and more thoroughly. If we transform our students into active learners through meaningful activities and if we make sure every student succeeds in every class, then our students can enjoy learning and meet the science education standards.

Achieving High Standards for All Students

In Green Hills High School, about one student per class failed each year. The total number of students who failed my classes over 20 years exceeded 100 students! One day, the assistant principal of the high school visited the schools science department meeting. Upset over the high rate of failure, he declared that, "You are not teaching science but teaching young people." After serious reflection, I realized that I did not have an excuse for failing so many students and my class should be a place where every student could succeed. In reality it was my teaching, not the curriculum or technology that would have the greatest impact on students' learning. I needed to change my instructional strategies to improve my students' performance. From that time onward, the first day of each school year, I declared, "Nobody is allowed to fail in my class. Failure is not an option." I began to re-teach when anyone failed and retested until he/she succeeded. Student reports were returned for revision when they did not meet my expectations. Initial grades given for assignments were either A, B, C or "Not yet." "Not yet" meant that the students could try again and revise their work to meet the requirements for an "A" or "B" grade.

There was zero failure in my classes for the last 10 years of my teaching in New Jersey. As the science department facilitator, I asked science teachers to practice the same policy but they were reluctant for fear of watering down performance. However, I argued that success at any cost is far more valuable than acceptance of failure. It took nearly three years, but all Green Hills public schools accepted this practice and required every teacher to allow re-teaching, re-testing, and re-visiting the assignments.

Ability Grouping

Green Hills High School had four ability groups: AP/honors, accelerated, regular, and modified. Recall that high schools in South Korea did not have separate ability groups but placed all students in college preparation courses. I often asked why American schools needed and wanted the ability grouping. I assumed this was so because we had different expectations for different groups of students and the students in the "low-ability group" would not be able to advance to colleges. Teachers' expectations were so low that their students in the

"low-ability group" did not have to study hard. I even question whether the "low-ability" group students really had "low ability" or if teachers assumed low ability because they thought these students could not succeed. As the facilitator of the science department, I decided to change the tracking system in that department. I kept a separate group of gifted students in an AP/honors group but required all other incoming freshmen to take an accelerated science course, with the option of contracting for any other level, such as the regular or modified levels, after one marking quarter. However, after the first marking period, as I anticipated, no one wanted to move to another level. I successfully eliminated the so-called "regular" and "modified" levels! I found out that American schools, like Korean schools, could demand high performance from all students.

Innovative Teaching Methods

The many forums of the MMSTEC conferences and summer academies inspired me to refine my beliefs in educational reform and helped me to produce fresh strategies of teaching to use in my science and mathematics teaching methods classes. As a result, my secondary education students have been involved in the following new teaching strategies:

- **Mathematics Integrated into Science.** Through collaborative teamwork, students develop curriculum projects that integrate closely related disciplines such as science and mathematics, history and mathematics, and geometry and art. It is expected that this type of project helps students learn more meaningfully, making their learning more relevant to their future, and thus influencing their own students learning. Integrating mathematics into science enhances the level of inquiry in science and makes mathematics more meaningful.
- **Inquiry Method.** Learning science has become "boring" through teaching methods that rely heavily on textbooks rather than hands-on inquiry activities. I strongly believe that meaningful inquiry activities help students become active learners because such activities allow them to construct their own ideas and retain their knowledge better. My participation in MMSTEC seminars and academies convinced me that inquiry-based learning could make a difference to students. Now I guide students to form essential questions as an excellent way to direct their explorations, concept acquisition and concept application.
- **Mathematical Modeling as Inquiry.** Students engage in an application of the inquiry model by deriving a mathematical model of the acceleration due to gravity. This application develops inquiry skills recommended by the National Research Council (NRC, 2000) for science students in grades 9-12 and mathematics standards of the National Council of Teachers of Mathematics (NCTM, 2000) to model physical, social, and mathematical phenomena, and determine the functions that model relationships. Modeling physical and biological systems by use of graphs and algebraic functions is a powerful tool for inquiry in secondary science and mathematics. Essential questions are developed to engage students in the inquiry and to guide their explorations.
- **Authentic Assessment.** Students engage in authentic assessment as they use the mathematical model in an inquiry activity that requires exploration, construction of concepts and application then write a laboratory report.

These teaching innovations center on the transformation of students into active learners engaged in meaningful activities, mainly through inquiry methods. In the sections that follow, I enlarge on these general descriptions of the teaching innovations with additional background and detailed examples of classroom activities.

These teaching innovations center on the transformation of students into active learners engaged in meaningful activities, mainly through inquiry methods.

Inquiry Methods in Secondary Science Classrooms

Guiding students to form essential questions provides an excellent way to direct students in their explorations, concept acquisition and concept application.

The inquiry model is consistent with the "Fundamental Abilities Necessary to Do Scientific Inquiry" proposed by the National Research Council (NRC, 2000) for Grades 9-12. These abilities include:

- Identifying questions and concepts that guide scientific investigations;
- Designing and conducting scientific investigations;
- Using technology and mathematics to improve investigations and communications;
- Formulating and revising scientific explanations and models using logic and evidence;
- Recognizing and analyzing alternative explanations and models;
- Communicating and defending a scientific argument. (p. 19)

Further, the National Science Education Standards note that "Inquiry is a multifaceted activity that involves making observations; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations." (p. 23)

Stages of Inquiry

Although inquiry methods have been implemented in science classrooms for many years, there has never been general agreement about their details. Most inquiry models begin with a student-centered exploration stage through which the teacher guides students to discover unknown results. In the second stage, concept acquisition, teachers present concepts and proper terminology to students. It is in this teacher-centered stage that the students must gain an understanding of the concept before moving on to the next stage. During the last stage, concept application, students apply concepts learned to new situations. This again is a student-centered stage. In this stage the students use the understandings they developed in the previous stages to predict the outcome of a new experiment (Marek, 1997; Tolman, 1999; Abruscato, 2000).

An initial focus for the students seems missing in many of these traditional inquiry methods that include only the exploration, concept acquisition and concept application stages. Peters and Gega (2002) added "invitation" to these three stages. The invitation stage includes questions or statements to increase student interest while leaving enough topics unclear to allow students to discover information through exploration. Elder and Paul (2002) explain the power of "essential questions" and claim that the quality of our thinking can be enhanced by the quality of our questions. Questions derived from our own real life experiences can generate more questions and stimulate new ways to think as we analyze and evaluate our thinking to improve our ideas. Guiding students to form essential questions provides an excellent way to direct students in their explorations, concept acquisition and concept application. According to *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (NRC, 2000), "Inquiry is intimately connected to scientific questions—students must inquire using what they know and the inquiry process must add to their knowledge." (p. 13). Therefore, science inquiry should include at least the following four stages: Essential question(s), exploration, concept acquisition, and concept application.

Thus, in a successful application of this inquiry model, students develop the essential questions to explore (invitation). Students, guided by teachers, design the experiment, collect and analyze data, graph and derive algebraic equations toward developing mathematical models (exploration). Then teachers assure students derive concepts from the mathematical model (concept acquisition). Finally, students think about ways of applying the concepts in new situations (concept application). Below I trace the development of these stages of inquiry through specific examples that are suitable for the secondary science classroom; I demonstrate these examples to the pre-service teachers in my secondary science methods course.

One Inquiry Activity in the Secondary Science Class

Using the proposed components of inquiry, students apply the inquiry model to derive a mathematical model to discover how a dynamic cart accelerates under a constantly acting force such as gravity.

Essential Questions (Invitation)

Aristotle (400 BC) claimed that heavier objects fall faster than lighter objects and that all objects fall at uniform velocities. These claims remained unchallenged for nearly 2000 years. Later, Galileo Galilei (1564-1642) hypothesized that objects do not fall at a constant speed, but accelerate. To test his hypothesis, Galileo used a ball rolling down an inclined plane. He reasoned that the ball's motion would be virtually the same as that of a freely falling body except that the inclined plane would simply "dilute" the force of gravity. The smaller acceleration would allow precise measurement of the "free fall" motion. Teachers can give this historical perspective. Students write essential questions such as:

1. What is the relationship between the position of an object under the force of gravity and the elapsed time?
2. What is the relationship between the velocity of the object under the force of gravity and the elapsed time?

Exploration

For the exploration stage, students use a spark timer and a tape (less than $20 per set from many science catalogs) to record the position of the freely falling object. They "dilute" the force of gravity by making a dynamic cart slide down an inclined dynamic track, or record the motion by using a motion sensor probe, an electronic data collection device (See Appendix I). When the spark timer is set at 60 Hz, every sixth marker (twin dots) represents 1/10 s and therefore the time (t) in seconds is incrementing by 0.1 s. Displacement (d) is the distance between every 0.1 s time interval, while Position (P) is the cumulative displacement after the total elapsed time. Velocity (V) is displacement divided by the time interval, which is 0.1 s in this exploration. After collecting the data, students then can organize the data (see Table 1, Appendix 2) and decide how best to proceed to address the essential questions. Graphing is a powerful way to proceed in this investigation.

Possible options include:

- *Graph 1: Position as a Function of Time* (See Appendix 4 for step-by-step methods of how to create this graph and the algebraic equation; See Appendix 3 for the graph of position vs. time). In this graph x represents the time and 1.96 is nearly equal to 2 (Graph 1), which predicts existence of a quadratic function.
- *Graph 2: Position as a Function of Time Squared* (See Graph 2, Appendix 5)
- *Graph 3: Velocity as a Function of Time* (See Graph 3, Appendix 6 which shows a direct relationship between the velocity and the elapsed time.)
- *Mathematical Modeling:* This section describes how to transform three algebraic equations produced by trend lines or curve-fitting into scientific equations.

From the Graph 1,

$$y = 153\ x^{1.96}$$

where y represents position (P) and x the elapsed time (t). Since 1.96 is nearly equal to 2, substituting,

$$P = (153\ \mathrm{cm/s^2})(t^2). \ldots \text{(Equation 1).}$$

From Graph 2,

$$y = 158\ x$$

where y represents position (P) and x the time squared (t^2). Substituting,

$$P= (158\ \mathrm{cm/s^2})t^2 \ldots \text{(Equation 2).}$$

This is showing that the position of the dynamic cart under the constantly acting force is directly proportional to the square of elapsed time. This equation is modeling the physical system of motion under a diluted gravity.

From Graph 3,

$$y = 279\ x$$

where y represents velocity (v) and x the elapsed time (t). Substituting,

$$V = (279\ \mathrm{cm/s^2})t \ldots \text{(Equation 3)}$$

showing that the velocity of the cart under a constantly acting force is directly proportional to the elapsed time, again modeling the physical system of a uniform acceleration.

I believe the most critical factor that can truly improve the science and mathematics education of American students is the commitment of dedicated teachers and the use of teaching strategies that employ inquiry-based learning, promote active learning, and facilitate opportunities for all students to succeed.

Concept Acquisition

Students develop the relationship between the two variables, position and time, and the concepts from $P = (158\ cm/s^2)t^2$ (Equation 2). It becomes clear that the position of the dynamic cart under a constantly acting force uniformly accelerates and that the position is directly proportional to the square of time. This is the answer to Essential Question 1, "What is the relationship between the position of an object under the force of gravity and the elapsed time?"

The third equation, $v = (279\ cm/s^2)t$ (Equation 3), shows that the velocity of the dynamic cart under the constantly acting force is directly proportional to the elapsed time, answering Essential Question 2, "What is the relationship between the velocity of the object under the force of gravity and the elapsed time?"

Concept Application

Students explore the nature of acceleration beyond the essential questions. They attempt to develop implications and new hypotheses, discussing the problem of friction associated with any study of motion.

Inquiry as Authentic Assessment

Through this inquiry, students are expected to learn the conditions necessary for uniform acceleration and the technique of developing and interpreting symbolic equations representing a physical system of motion. Since students are engaged in an inquiry activity that requires invitation, exploration, construction of concepts and application, it is appropriate for them to write a laboratory report. For assessment of such laboratory reports, a Laboratory Report Assessment Rubric is presented in Appendix 7. Assessment based on clearly stated outcomes of learning is an example of authentic assessment that measures what each student learned and achieved.

Ensuring Success for All Students

As shown by this example of inquiry where technology and algebraic equations are used to model a physical system, mathematical modeling becomes an effective and meaningful tool for inquiry in science. Algebraic equations, when transformed into scientific equations, become not only powerful in representing the physical system but also in making mathematical relationships meaningful. From such equations, students can construct their own ideas about the physical system and derive the relationship between two variables, independent and dependent. Mathematical modeling is a powerful tool in scientific inquiry to assure success for all students.

Throughout the semester, my education students conduct mathematical modeling through inquiry. My hope is that these students share my beliefs, practice the same type of inquiry in their teaching and participate in 21st century educational reform. I believe the most critical factor that can truly improve the science and mathematics education of American students is the commitment of dedicated teachers and the use of teaching strategies that employ inquiry-based learning, promote active learning, and facilitate opportunities for all students to succeed. We, as college instructors, have a tremendous challenge to adequately educate our future science and mathematics teachers to assure success for all students.

After growing up in Korea and graduating from Korea University in 1961 with a B.S. degree in physics, Chuck Kim came to the United States in 1968 and taught high school science in New Jersey from 1969 until 2001. During his 31 years of teaching, his greatest challenge was to understand why so many students failed each year. When he began to teach science and mathematics education methods courses at the University of Maine at Machias in 2001 and after participating in MMSTEC activities, he began to refine the inquiry method as an effective instructional strategy for teacher candidates to use.

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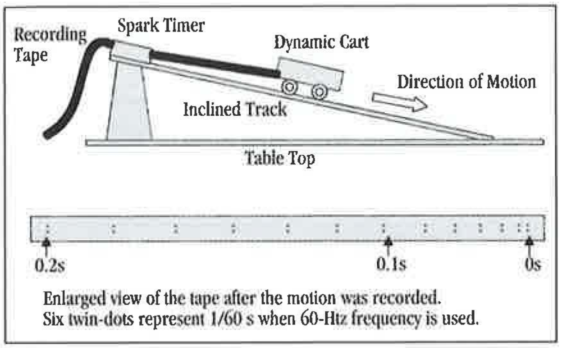
APPENDIX 1

Recording the Motion of a Dynamic Cart on an Inclined Track



APPENDIX 2

TABLE 1.

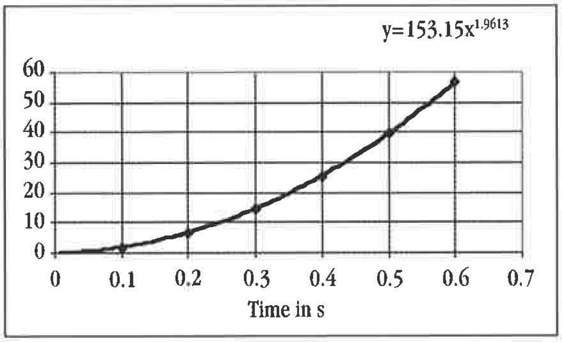
POSITION AND VELOCITY AS A FUNCTION OF TIME

Time s (t)	Time s² (t²)	Displacement cm (d)	Position cm (P)	Velocity cm/s (V)
0	0	0	0	0
0.100	0.010	1.7	1.7	17
0.200	0.040	4.7	6.4	47
0.300	0.090	7.9	14.3	79
0.400	0.160	11.0	25.3	110
0.500	0.250	14.3	39.5	142
0.600	0.360	17.4	56.9	174

APPENDIX 3

GRAPH 1.

POSITION AS A FUNCTION OF TIME



APPENDIX 4

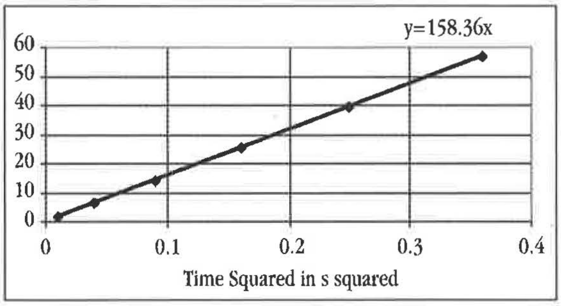
How to Use Excel to Make Graphs and Algebraic Equations

Graph 1 and the algebraic equation were produced by Excel as follow:

1. Select Cell A2 (the first column including the column heading) through Cell A9 and Columns D2-D9, holding down Ctrl key to skip Columns B-C, and click Chart Wizard icon.
2. From Step 1 of 4, select X-Y (Scatter) and go to Next.
3. In Step 2 of 4, make sure the Series In is Column and got to Next.
4. In Step 3 of 4, keyboard the Chart Title, label X and Y axes, enable Major Gridlines for X axis, disable Show Legend from Legend, and go to Next.
5. Click Finish in the Step 4 of 4. Graph is now completed.
6. To produce the algebraic equation, right-click on one of the data point and select Add Trendline.
7. Select Power Function, go to Option tab and enable Show Equation before finishing.

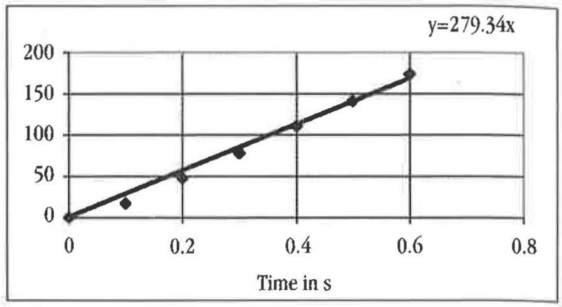
APPENDIX 5

GRAPH 2.
POSITION AS A FUNCTION OF TIME SQUARED



APPENDIX 6

GRAPH 3.
VELOCITY AS A FUNCTION OF TIME



APPENDIX 7

Laboratory Report Assessment Rubric

Title						
Name						
Date		0	1	2	3	4
Title Page	Shows all the necessary information.					
Format	Uses proper lab format & reference to tables and graphs.					
I. Essential Questions	States the essential questions.					
II. Exploration	Lists the instruments and chemicals used.					
	Lists the steps required to replicate the experiment.					
A. Data Tables	Gives a proper title of table and column headings.					
	Uses an appropriate orientation.					
	Makes correct computations.					
	Uses units of measure.					
	Observes significant figures and rounding-off rules.					
B. Graphs	Gives a proper title and a legend for each·axis					
	Uses an appropriate orientation.					
	Shows units of measure.					
	Produces trend lines and mathematical equations.					
C. Analysis of Data	Shows necessary computation work.					
	Uses symbolic equations.					
	Identifies the source of equation					
	Utilizes dimensional analysis.					
	Evaluates accuracy and precision.					
D. Mathematical Modeling	Identifies the source of equation.					
	Defines each symbol used in equations.					
	Develops the final scientific equation.					
III. Concept Acquisition	States the essential questions.					
	Presents the relevant experimental results.					
	Presents the scientific equations from mathematical modeling.					
	Discusses the relationship between variables.					
IV. Concept Application	Examines the validity and major causes of error.					
	Proposes implications and methods of improvement.					
Data Book	Attaches a handwritten record of laboratory work.					
Total Score						

The Development of an Educator

Malcolm Holmes

NSF Noyce Scholar
University of Maine at Machias
Malcolm01957@yahoo.com

This paper details the author's development from a non-traditional student who did not understand the challenges or complexities of education, to an inspired, well-equipped pre-service teacher. His preconceived educational ideas were changed as a result of his experiences in the classes at the University of Maine at Machias, watching experienced teachers teach in real world situations, and working with educational mentors, such as those who volunteered their time in the MMSTEC program.

Introduction

I have often heard it said that good teachers are born with the gift for teaching. While it is probably true that some individuals have more of an aptitude to teach than others, I believe that all teachers are the sum of their personalities, life experiences, and the training they receive on the way to becoming a teacher. The education and experience pre-service teachers receive is crucial in the development of effective educators. In addition to my educational opportunities at the University of Maine at Machias (UMM), an important part of my personal development as a teacher has been my involvement with the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC) and the dedicated professionals who contributed their time and energy.

Personal Background

To fully understand the impact that UMM and MMSTEC has had on my development, it is important to understand my background. I was born in 1957. At the age of three I lost both of my parents. My siblings and I were sent to different foster homes. Compared to most foster children I had a fairly stable childhood, although I received little parental support for my educational development. During high school I was not considered to be college material by either my foster parents or my high school. When I graduated in 1976 I had few options; college was definitely not one of them.

I entered the Air Force, and was soon married. My wife and I had three children in the first six years of our married life. Because of the loss of my first family, I always wanted children and considered my children to be central in my life. I now had the family that I always wanted, but my lack of education left me with a desire to go back to college. I had educational opportunities while serving in the Air Force ranging from learning in a traditional classroom environment to the experiential learning associated with exposure to different worldwide cultures.

My Air Force career was successful. When I retired in 1995, I was awarded the Air Force Meritorious Service Medal for outstanding service. After retiring I held a variety of jobs, all of which left me dissatisfied. For years I had found fulfillment and satisfaction in the service of my family and the Air Force. During those years in the Air Force, my wife and I raised three wonderful children. With one child married and the other two children mostly grown we became aware of a situation where three children needed a home. In 1999, my wife and I became involved in foster care, taking this family of three children into our home. Three years later we adopted all three children increasing our family size to six, ranging in age from four to twenty-four.

At this point, I once again became dissatisfied with my job. Each of my past employers had been happy with my performance and work ethic, but I felt that I was only working for a paycheck. Making a living was not enough. I wanted to be challenged by my work, while at the same time make a positive impact on those around me. My wife encouraged me to take advantage of my GI bill and return to college.

Beginning the Quest

At each step of the way both my education professors and science department professors constantly assisted me in the development of both my core body of knowledge and the skills that I would need as an educator to share that knowledge with my students.

In January 2000, I visited Washington County Technical College (WCTC) on a whim. I enrolled in Technology and Liberal Studies, a dual degree program. I found myself enjoying school and doing quite well. I was encouraged by several of my professors at WCTC to consider entering the education profession. The Veterans Administration (VA) professional who evaluated me confirmed that I did have an aptitude for teaching. I have always admired teachers and wished that I had the intelligence and ability to be one. I love learning and I have always enjoyed working with children. I wanted to be a teacher, but was not sure if I had what it would take to complete the required program. It is one thing to have others see my potential as an educator; it is an entirely different thing to believe it myself. At the age of 44, I found myself caring for aging parents, as well as dealing with the many other commitments that come with middle age. With the support of my wife and family, I continued my education at WCTC completing the degrees in Technology and Liberal Studies before matriculating to UMM with the goal of becoming a high school science teacher.

The Pathway to Education

My first experience at UMM was a one-hour campus tour with Dr. Chuck Kim a mathematics/science education professor. He was both helpful and inspirational. During the next three years at UMM, Dr. Kim, in concert with several other professors, was a constant source of encouragement for me. The work and time required to earn a degree in biology is difficult, but combining this degree in biology with the development of skills necessary to manage a classroom, develop a curriculum, and engage students in a way that would ensure their success, was intimidating. At each step of the way both my education professors and science department professors constantly assisted me in the development of both my core body of knowledge and the skills that I would need as an educator to share that knowledge with my students.

In addition, the experience and encouragement of the educators involved with the MMSTEC program kept me focused on my original goal of becoming a high school science teacher. Several times during my education I have considered taking my biology degree and going into one of several other careers that would have been open to me. Being surrounded by individuals, such as those involved in MMSTEC who were passionate about education provided the inspiration I needed to make it through the trying times. In the spring of 2006 I will have completed my student teaching, achieving my goal of a degree in Biology with a minor in Secondary Education. Additionally, I will have completed more than the required course work for certification in both life science and physical science.

Influences Along the Way

I was told that with my background that I should be an effective teacher. Looking back at the misconceptions with which I began my education courses, I can clearly see that I was not ready to become a teacher. For example I thought that:

- Teachers worked a short day with holidays and summers off.
- If discipline in the classroom were firmly applied, all students would learn.
- Test results were used as leverage to force students and their parents to take school seriously.
- Special education students were often seen as behavioral problems that classroom teachers did not want to deal with.
- Students needed less technology and more practical work.

Now, thanks to the effort of professionals who have invested their time in me, my misconceptions and preconceived notions have changed. I have a whole new perspective on education. Dr. Kim has been most influential in the formation of my philosophy of education. Dr. Kim champions inquiry-based education and integrated curricula. He believes all students can be successful. In Dr. Kim's classes, opposing points of view are encouraged. Over the past three years, I have had several education courses with Dr. Kim as well as attending numerous MMSTEC seminars with him. At first I felt that Dr. Kim's philosophy toward education could not possibly work. I argued that troubled students and troubled school systems needed a firm hand if an effective educational environment were going to be developed. Dr. Kim's view of education would not fit into the school system that I envisioned. Fortunately, having the opportunity to work with numerous educational professionals who use inquiry methods in conjunction with integrated curricula has shown me that Dr. Kim's philosophy toward education is indeed correct. I firmly believe that if students are engaged in a curriculum that is both inquiry-based and integrated they will not only develop a strong foundational knowledge, but will also develop the tools and desire necessary to become lifelong learners. Students are on an educational journey that should ensure that each student has the opportunity to reach his or her full potential. An effective teacher will facilitate that journey.

Additionally, observing teachers in the classroom, working as a substitute teacher, and working as a tutor have influenced my thinking and provided new insight into the education process. For example, during my first practicum, I observed a high school physics/calculus teacher. My eyes were opened. He arrived at school before seven in the morning, left between four and five in the afternoon, took home a large amount of work, and normally worked half a day on Saturday getting ready for the following week's classes. Mixing in meetings with students, parents, and administration was a part of his weekly routine, not to mention participation in after school activities. Being a teacher is not for the faint of heart.

In addition to the financial support through Noyce Scholarships, MMSTEC through professional development experiences has been influential in giving me the tools and confidence that I need to be successful as an educator. Dr. Kim had told me what the atmosphere at an MMSTEC conference would be like, but I was amazed to find highly educated and experienced individuals asking me questions, wanting to know what I thought about our educational culture and its problems. The support of education professionals involved in MMSTEC has been inspirational. Through MMSTEC, I have met individuals at every level of education who have shared their personal life experiences and their thoughts on education. I have been encouraged to believe that I do have what it takes to be an educator. I have been given the tools needed to be a more effective teacher. I have been given resources to turn to when I run into problems, and I know that there will be problems. I now understand that one of the keys to being an effective educator is ongoing professional development, both formal and informal, as well as, sharing experiences with peers and mentors. I will never forget my first MMSTEC conference as I listened to an excited professor from the University of Maine, Farmington talk about how she used assessments to evaluate her own teaching methods. I had never considered that assessments could be used to evaluate a teacher's own performance!

I firmly believe that if students are engaged in a curriculum that is both inquiry-based and integrated they will not only develop a strong foundational knowledge, but will also develop the tools and desire necessary to become life long learners.

Conclusion

In today's society there is a need for mentors to get involved in the development of our young men and women. MMSTEC has provided those badly needed teacher mentors to pre-service mathematics and science teachers such as me. At each of the MMSTEC conferences, I have been surrounded by encouraging mentors who were essential in the development of my views toward education. Not since serving in the Air Force have I felt that I can once again make a difference, giving children from all walks of life (including foster children like me) the tools necessary to be successful in today's society. The money, time, and energy that have been invested in MMSTEC will reap benefits for Maine and the United States for years to come.

In conclusion, I want to end this paper with a story of fulfillment. Some students are not easily motivated, some do not have the background knowledge, and some do not have supportive families, all of which makes the teaching process extremely challenging at times. However, when a student succeeds, all of the hard work is worthwhile. One student I was tutoring in biology gave me a card with the following note.

"Well we did it, I passed!!! Thank you so much for all of your help. I couldn't have done it without you. I know I was not always the best listener, but you kept me on track. Thanks."

Malcolm and his wife of 29 years have six children, three biological and three adopted, ranging in ages from 8 to 28 as well as six grandchildren. He retired in 1995 from the Air Force. In December of 2005 Malcolm completed his biology degree with more than the required course work for certification in both the physical and life sciences. Malcolm will be student teaching in the spring of 2006.

Journeys of Classroom Change

Implementing a Student-Centered, Inquiry-Based, Constructivist Pedagogy in a High School Physics Classroom: The Modeling Method of Physics Instruction

Jeffrey J. Steinert
Physics Instructor
Edward Little High School, Auburn, Maine
jsteinert@auburnschl.edu

This paper describes implementation of the modeling method for physics instruction in high school classes. The discovery that traditional teaching methods were not resulting in substantial gains in student learning led to the author's participation in NSF-funded regional Leadership Modeling Workshops provided through Arizona State University. The experience had an immediate and lasting impact on his instructional pedagogy, teaching effectiveness, personal professional development and service to the teaching profession. A discussion of the application of the modeling cycle and the results of Physics Education Research to the development of activities promoting student understanding of Newton's third law is also provided.

Introduction

I teach regular and honors physics classes to seniors at Edward Little High School, the public secondary school in Auburn, Maine. In the winter of 1997, I had been teaching physics for ten years, and had developed what I thought was a clear and convincing series of lectures, demonstrations, and laboratory activities through which my students could assimilate the concepts of Newtonian mechanics with little effort or engagement. As we began our study of work and energy, it became apparent to me that more than a few students did not recall that forces caused objects to accelerate but had regressed to their Aristotelian belief that force was necessary to sustain motion. Just a few weeks earlier these same students had been able to correctly apply Newton's laws to solve problems and answer questions in classroom discussions. Why had they forgotten what they knew? Had they never truly learned the concepts? Was there a more effective way to teach introductory physics? One month later, out of the blue, a friend sent me an *American Journal of Physics* article describing the effort David Hestenes of Arizona State University was leading to disseminate the modeling method of physics instruction on a nationwide level (Wells, Hestenes & Swackhamer, 1995).

The Modeling Method of Physics Instruction

Leadership Modeling Workshops

In the summers of 1998 and 1999 I was privileged to spend four weeks at a Leadership Modeling Workshop at the University of Maryland learning the modeling method of physics instruction and an additional four weeks developing modeling curriculum materials for second semester topics at St. Albans School in Washington, DC. Our workshop co-leaders had received similar training in the summers of 1995 and 1996. They were experienced practitioners of the modeling method and well versed in the Physics Education Research (PER) on which the pedagogy is based. Workshop participants initially played the role of students, but gradually assumed more and more of the responsibilities of teaching as we worked through the entire mechanics curriculum. An essential feature of the workshop was the emphasis placed on exposing participants to

...the modeling method is designed to engage students in understanding the physical world by constructing and using scientific models to describe, explain and predict physical phenomena.

issues regarding student comprehension of Newtonian mechanics. This was accomplished through readings from the PER literature (Beichner, 1994; Hestenes, 1997; Hestenes & Halloun, 1995; Hestenes & Wells, 1992: Hestenes, Wells & Swackhamer, 1992; McDermott, 1993; Mestre, 1991) and from Arnold Arons' text, *Teaching Introductory Physics* (Arons, 1997). The Leadership Modeling Workshop was far and away the best professional development experience of my career. It revolutionized and rejuvenated my teaching and I now use the modeling method in all of my classes.

The Modeling Method Pedagogy

Developed by high school physics teacher Malcolm Wells and based on the findings of PER, the modeling method is designed to engage students in understanding the physical world by constructing and using scientific models to describe, explain and predict physical phenomena. It is in full alignment with both the National Science Education Standards and Maine's Learning Results, especially in its employment of student-centered, inquiry-based pedagogy and support for authentic assessment and collaborative interactions among learners. It has twice been honored by the U. S. Department of Education as one of seven exemplary or promising educational technology programs and as one of two exemplary science programs (http://modeling.asu.edu).

Instruction is organized into cycles that consist of two stages: Model Development and Model Deployment. Throughout the modeling cycle I have a definite agenda and specific goals and objectives for every classroom activity. Management of this agenda is done unobtrusively; I assume the roles of facilitator, arbiter and inquisitor instead of being the expert.

Model development in each unit begins with a paradigm lab: a toy car traveling across the table at a constant speed, a cart accelerating down a ramp, a ball being shot from a projectile launcher, two lab carts colliding. The students decide, as a class, everything that could affect the motion in each situation, reducing the list to those variables they can control, measure, or both, and identify a purpose for their investigation. Each lab group then designs and conducts their own experiment to accomplish that purpose using the equipment available to them.

Data collection and analysis is performed cooperatively, using computer-based sensors and graphing programs to construct graphical and mathematical representations of the motion being studied. For the constant velocity lab, most students use stopwatches or motion detectors and for the accelerated motion investigation, a photogate and picket fence. To make the motion of the projectile observable, video images of the trajectory are analyzed using Logger Pro software. In the collisions lab, motion detectors and force sensors are employed to investigate the relationships among the applied forces and masses and velocities of the carts. Extensive use of technology shortens the time required for manipulation of data and provides greater opportunities for students to analyze the results of their experiments.

Investigations conclude with each team preparing a detailed analysis of their results and the reasoning that led to their conclusions. Students are encouraged to develop their models using verbal, graphical, algebraic and diagrammatic representations. These are presented on small whiteboards, with selected groups explaining and defending their experimental design, data analysis and proposed model. Unlike traditional laboratory exercises, where confirmation of known relationships is the goal, the end product of this process is a student-derived statement of the physical laws that govern the situation being studied.

During student presentations, I ask questions—Why did you do that? How do you know that? Students are encouraged to pose questions as well. One of the keys to making the modeling method work is to establish an atmosphere in which everyone, including me, is part of a team trying to learn something about how our universe works. Because I remove myself from the position of authority, students must rely on each other to evaluate their work. Only at the end of the post-lab discussion do I help the class pull together all they have learned from the presentations and summarize the model they have developed.

The second stage of the modeling cycle is devoted to deployment of the model in a variety of new physical situations to emphasize its applicability outside of the specific context in which it was developed. This may involve the use of the model to design additional laboratory activities, to solve traditional problems or to describe, explain and predict the results of a laboratory practicum. In any case, the in-class work is done cooperatively in small groups. This is a particularly advantageous approach

to homework because it provides students with multiple opportunities to understand the solutions to the assigned problems and the underlying concepts on which they are based. The first comes when they attempt the problems as homework, the second when their group discusses the assigned problem in the course of preparing a solution on a whiteboard and the third when one group member presents the solution to the class and fields questions.

The worksheets developed by teachers as part of the Modeling Workshop Project at Arizona State University include many questions adapted from published PER and pose conceptual difficulties for students who have non-Newtonian preconceptions about the world around them. They are designed to provide opportunities to address these difficulties by inducing students to articulate, analyze and justify their personal beliefs. When students are required to do this, it provides me with the necessary insight into their thinking to make informed instructional decisions about what further activities will best address their needs. The curriculum materials for mechanics are available free to all visitors to the modeling website (http://modeling.asu.edu/Curriculum.html) and may be used in their original form or adapted to better fit the needs of particular classes or individual students.

One of the great strengths of the modeling method of physics instruction is the opportunity it provides for interaction between and among the students and teacher. As I circulate while students prepare whiteboards I am continually eavesdropping on student discussions, asking questions when appropriate, and making notes about what points need to be addressed in each presentation. In this manner, I can quickly determine students' initial understanding and monitor their progress. On occasion, a group will reach an impasse, either because of disagreements about their solution or due to incomplete understanding of the concepts necessary to proceed. In those instances, I use a form of Socratic dialogue (Hake, 1992) to bring them back to the model they developed in the paradigm lab and assist them in determining how it can be applied in the current situation. The discussions that ensue are often so valuable that I will ask the group to whiteboard their original, incorrect, solution to generate the same exchange of ideas with the entire class. The actual presentation of whiteboards becomes a celebration of peer and self-assessment through which I can also gauge students' mastery of concepts. Students are usually eager to share their thinking and ask intelligent and insightful questions of one another once they have been shown how to work together toward a common goal.

Implementing the Modeling Method

Adopting an interactive-engagement approach to teaching physics requires that the number of topics be reduced to provide time for students to construct their own knowledge and acknowledgment that some students, parents and administrators may not react positively to the pedagogical techniques employed. Many teachers have had pupils complain that they are "not teaching" because they do not provide all of the answers, instead requiring students to struggle to think through and reach their own conclusions. Some have been directed by administrators under pressure from students and parents to change their instructional practices and a few have even subsequently lost their jobs.

My experience implementing the radical change in pedagogy involved in adopting the modeling method was very positive. Prior to attending the Leadership Modeling Workshop I informed and educated the administration in my school district about the changes I would be making and their effect on both the conduct of my classes and the content of the courses. They encouraged my attendance at the workshop and pledged financial, technological and prep time support for my efforts. I was also successful in acquiring nearly $10,000 in computers, interfaces and sensors through a grant from Bates College funded by the Howard Hughes Medical Institute. This equipment completed a six-station microprocessor-based laboratory and allowed me to fully integrate computer-based investigations and activities into my courses. On the first day of class, I make a point of explaining to students how their physics course will be very different from any of their previous science classes and how it will work to their benefit. This has proven effective in heading off any misunderstandings about the teaching methods I employ. In the seven years since I implemented the modeling pedagogy in my classes, I have had both students and parents comment on how much they or their child enjoy physics but have not received a single complaint about the conduct or the content of my classes.

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The Role of Assessment in the Design of Student Activities

Knowing what to ask and when is often more art than science and requires both a knowledge of common student misconceptions and a minimum of several years experience in managing discourse in the classroom. It is the component of the modeling method I strive to improve upon most each year.

Assessment of Student Progress and Achievement

The modeling method provides many opportunities for the instructor to assess student understanding of the topic at hand. As mentioned above, circulating during whiteboard preparation allows me to gain an overall feel for the comfort level of the class while engaging students individually on concepts that PER has determined are commonly misconstrued. Careful attention to the language a student uses in explaining his or her answers in one-on-one conversation or during a whiteboard presentation is often the key to unlocking what they are thinking. Sometimes it is one last clarifying question that brings out the alternative conception and ignites the class into a new dialogue about how to interpret the results. Knowing what to ask and when is often more art than science and requires both a knowledge of common student misconceptions and a minimum of several years experience in managing discourse in the classroom. It is the component of the modeling method I strive to improve upon most each year.

To incorporate more authentic assessment into my classes, I have developed physics practica to assess student mastery of scientific knowledge and reasoning for each unit. The constant velocity practicum challenges students to predict the time and position at which two cars moving at different constant velocities will meet and the static force practicum requires them to determine the mass of a hanging object based on the tensions and angles of the supporting strings. For the projectile practicum, I fire a dart from a blowgun into the bulletin board at the front of the room, cover the dart and ask each group to determine the angle at which the dart is sticking into the wall. To successfully complete this task, students must measure the angle of the blowgun and the horizontal and vertical displacements of the dart and use them to determine the initial velocity, time of flight and final angle of the dart. It is sometimes difficult to stand by quietly as students struggle with decisions about what to measure, how to apply the information they have and how to present their solution, but the sense of accomplishment they have when we uncover the dart and confirm that they were within a degree of the actual value is indescribable. The fact that it is the apparatus that tells them they are correct and not the teacher makes the validation all the more powerful.

In addition to the assessments described above, I also employ the Force Concept Inventory (FCI) and other research-based diagnostics as summative assessments to evaluate the effectiveness of my instruction and make curriculum decisions for subsequent years. The FCI has been demonstrated to provide a valid and reliable measure of students' conceptual understanding of Newtonian mechanics (Hestenes, Wells & Swackhamer, 1992). A six-thousand-student study (Hake, 1998) found the average FCI pretest/posttest normalized gain

$$\left(gain = \frac{Post\% - \mathrm{Pre}\%}{100 - \mathrm{Pre}\%} \right)$$

for all students after traditional instruction in introductory physics was 0.23 (std. dev. 0.04). In contrast, Hake found that students in interactive-engagement courses had an average normalized gain of 0.48 (std. dev. 0.14). Results for my College (regular) and Honors Physics courses taught using the modeling method are summarized in Table 1. My gains are similar to those reported by Hake for all interactive-engagement courses and are between one and three standard deviations higher than those for traditional instruction.

TABLE 1
FCI PRE/POSTTEST SCORES AND GAINS (N = NUMBER OF STUDENTS)

Academic Year	College (regular) Physics				Honors Physics			
	N	Pre %	Post %	Gain	N	Pre %	Post %	Gain
1998-99	56	26	47	0.29	21	31	57	0.38
1999-2000	50	28	53	0.35	21	35	66	0.48
2000-01	55	29	57	0.39	11	27	69	0.58
2001-02	46	27	53	0.36	25	36	78	0.66
2002-03	60	27	54	0.37	20	37	69	0.51
2003-04	49	24	47	0.30	26	31	67	0.52
2004-05	33	25	55	0.40	13	39	78	0.63

Each year, I use an item analysis of my students' FCI posttest scores to identify areas of weakness in their understanding and revise classroom activities to address them.

Design and Revision of Student Activities

Each year, I use an item analysis of my students' FCI posttest scores to identify areas of weakness in their understanding and revise classroom activities to address them. One of the first times I did this, I discovered that many often-missed questions centered on concepts directly related to Newton's third law. The original modeling activity on this topic was a worksheet that presented a series of twelve different situations in which blocks of equal or unequal mass pushed or pulled on one another while moving at constant velocity or accelerating. Students had to state the relationship between the forces the blocks exerted on one another and then make a force diagram for each block. I revised the activity so that students first predicted the forces the blocks exerted on one another and then used two computer-based force sensors to actually measure them. I also had them sketch system schema, diagrammatic representations of the interacting objects and the resulting forces (Turner, 2003), and inserted a background grid that required them to construct their force diagrams to clearly indicate the quantitative relationships among the forces acting on each object. This transformed the activity from one in which students merely applied Newton's third law to one where they discovered the relationship between the third-law pair for themselves in a variety of different dynamic situations.

A recent paper in which the authors (Bao, Hogg & Zollman, 2002) developed a multiple-choice survey by examining contextual features that lead to misconceptions about forces acting between objects prompted me to further revise my third law activity. They found that many students consistently employ a dominance principle when describing the forces acting on objects. The object that is actively pushing or has the greater mass or velocity is invariably determined to exert the greater force. In order to incorporate all of these contextual features into my third law unit, I revised my activity to include situations in which the objects move independently of one another prior to colliding. The impulsive nature of the forces makes measuring and displaying their equality more difficult and students must be led to describe the velocity and acceleration of each object independently prior to constructing their force diagrams, but the resulting discussions regarding the dynamics that produce those motions have been most profitable for my students.

Professional Development, MMSTEC, and Impact on Science Instruction

Professional Development Opportunities

In addition to the outstanding professional development the Leadership Modeling Workshop afforded me, my association with the Modeling Workshop Project has provided numerous opportunities to share my expertise in a variety of forums. In 2000 and 2001, I co-led workshops for middle and high school physics teachers at the University of New England that were funded by the Maine Mathematics and Science Alliance. In 2003, I shared my story and data documenting gains in student conceptual understanding with colleagues at the MMSTEC Midyear Conference. Since then, I have co-led workshops at Florida International University in Miami (2003-2005) and Bridgewater State College in Massachusetts (2005). I have found sharing the modeling pedagogy and my own experiences in implementing it with other physics instructors to be one of the most rewarding experiences I have had as an educator. Participants in every workshop have been actively interested in improving their mastery of content, teaching skills and knowledge of PER, and have responded enthusiastically to what we, as workshop leaders, have to offer.

I have found sharing the modeling pedagogy and my own experiences in implementing it with other physics instructors to be one of the most rewarding experiences I have had as an educator.

Funding from the Howard Hughes Medical Institute (HHMI) allowed me to found the Central Maine Physics Alliance (CMPA) in 2003 to address the isolation that often afflicts secondary physics teachers by creating a forum in which local instructors regularly meet to discuss physics education issues, the latest research on teaching and learning, and share ideas for improving student conceptual understanding. The CMPA continues to receive funding through Bates College where we meet on a monthly basis. In the coming year, we plan to provide workshops for elementary and middle school science teachers to assist them in designing and creating classroom activities aligned with the Maine Learning Results to address common student preconceptions.

MMSTEC's Impact on Science Instruction at Edward Little High School

Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC) has had a direct impact on science teaching at my school. In the fall of 2003, Lauren Traynor, an MMSTEC NSF Scholar, student-taught in my physics classroom as part of her program at the University of Maine at Farmington. Her knowledge of content and pedagogy were impressive and she was hired to fill a vacancy at the end of the year. Miss Traynor has become a valuable asset to our department and, as her mentor teacher, I have learned much from her and continue to profit from the advantages of having another physics instructor in the same building.

Next Step: Professional Development Needs

Providing for Continuing Professional Development

A combination of grants from HHMI and the Toshiba America Foundation and a local bond issue have provided the physics, chemistry and physical science classrooms at Edward Little High School with fully-equipped computer-based laboratories. Teachers have taken advantage of professional development opportunities provided by National Science Foundation funded initiatives such as the Modeling Workshop Project, Activity-Based Physics, and Constructing Physics Understanding to gain the technical and pedagogical skills necessary to deliver high quality instruction. Departmental workshops have allowed individuals to share their expertise with colleagues, but the desire for sustained professional development has often fallen victim to the need to devote increasing amounts of time to developing Local Assessment Systems, preparing students for MEA testing and documenting student achievement of Maine's Learning Results.

Nearly five years ago, the Glenn Report, *Before It's Too Late,* (U. S. Department of Education, 2000) called for a five billion dollar annual expenditure to create exemplary teacher preparation programs and sustained, high quality professional development to address the looming shortage of qualified mathematics and science teachers. Regrettably, that vision has not been fulfilled and the need for such programs remains. MMSTEC has provided a clear vision of what can be achieved when instructors are empowered to take risks and provide students and future educators with innovative approaches to learning and teaching. My hope is that the good start we have made can be sustained over the long term and deliver some of the benefits anticipated by the authors of the Glenn Report.

Jeff Steinert has taught high school physics for 20 years in California, Massachusetts and Maine. He earned his bachelor's degree in biomedical engineering from The Johns Hopkins University and his master's in mechanical engineering from the University of California at Berkeley. The work of Arnold Arons and Robert Karplus sparked his interest in physics education research and led to participation in Arizona State University's leadership modeling workshops in the summers of 1998 and 1999. He has since led numerous summer modeling workshops for high school and college physics instructors at the University of New England and at Florida International University.

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On Teaching Geometry to Pre-Service Elementary Teachers, II

Elizabeth S. Allman

Department of Mathematics and Statistics
University of Southern Maine
eallman@usm.maine.edu

This article describes the author's experience teaching geometry to pre-service elementary teachers at the University of Southern Maine as part of the Maine Mathematics and Science Teaching Excellence Collaborative. Reflections on a mathematician teaching pre-service teachers and discussion of broader issues of improving pre-service mathematics teacher training are included.

Introduction

In fall 2000, I started in a joint position in the Department of Teacher Education in the College of Education and Human Development (CEHD) and the Department of Mathematics and Statistics in the College of Arts and Sciences (CAS) at the University of Southern Maine (USM). The National Science Foundation funded my position for five years, as part of an ambitious project to improve mathematics and science teacher training in Maine. This project, the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC), is statewide in scope and involves faculty from the University of Maine system and local schools. Though the goals and activities of MMSTEC are broad, worthy, and myriad, certainly deserving of study and commentary, this manuscript will focus exclusively on my experience teaching geometry to pre-service elementary teachers as part of the MMSTEC project.

My academic background is in mathematics and I was trained as a researcher, though I have always had a strong interest in teaching. Indeed, my desire to teach at the college level prompted me to enter graduate school after several years of high school teaching and one year working at a computer company. I first became involved with teacher training as a graduate student at UCLA, where I was in charge of training and evaluating teaching assistants. Though I enjoy children very much, I had little experience with elementary education before beginning in this innovative joint position.

At USM, about ninety undergraduate pre-service K-8 teachers participate in the TEAMS program, Teachers of Elementary and Middle School. In design, TEAMS students work towards an undergraduate major simultaneously with completing professional teacher education requirements. A popular drawing point of TEAMS is the opportunity for extensive work in local schools throughout the entire program. Due to its demanding nature and broad scope, the program is 4.5 years in length.

Though state content requirements for certification are in flux, currently TEAMS students must take three mathematics courses: Number Systems for Elementary Teachers, Introduction to Statistics, and Geometry for Elementary Teachers. Of these three courses, only the statistics course is not designed specifically for TEAMS students; undergraduates with varying interests and backgrounds study beginning statistics and TEAMS students make up a small fraction of the students in any class.

Teaching Geometry for Elementary Teachers

My experience with teaching pre-service elementary teachers is limited to the Geometry course, MAT 232. In many ways, this is an odd choice for me as my mathematical background is in algebra and I have never particularly liked Euclidean geometry. In addition, I have no talent for model building, and in preparing to teach the course for the first time I was worried since I thought (and still believe) that hands-on experiences for the students would be best.

I have now taught MAT 232 two times, first in spring 2001 and again in spring 2004. The experiences were very different. I have learned a tremendous amount about the challenges of teaching such a course and understand better the larger issues, those facing university and pre-service K-8 teachers nationally.

One of the oddities of the Maine teachers' licensure rules is that certification brackets in Maine are K-8 and 7-12; there is no separate certification for middle school teachers, though either of the two certifications is sufficient for middle school teaching under current law. This confounds the already difficult task of preparing highly qualified middle school mathematics teachers. Pre-service teachers in MAT 232 display a remarkable disparity in background, interest, and knowledge, and have very divergent needs: middle school mathematics teachers would benefit from much more rigorous mathematical training than that necessary to teach first or second grade.

Since my experiences teaching MAT 232 have been so different, courtesy compels me to outline the two courses—pedagogical foundations, assessment structure, student reaction—to allow the reader to best understand and judge my discussion below.

During spring 2001, eleven students took MAT 232. Nine of them were TEAMS students, one was an in-service seventh grade mathematics teacher and one was an "Ed-tech" working towards her 7-12 mathematics certification. The class met once a week on Mondays, from 4:00-6:30. Unfortunately, because of holidays and snow days, three of these meetings were cancelled. This cast a shadow over an already disjointed and difficult semester.

The breadth of ability in this class was like nothing I have ever seen before or since. Two of the students had taken several sophomore-level mathematics major courses (including differential equations) and were misplaced in MAT 232. They were deeply angry in fact because they had been poorly advised and told they must take this course as TEAMS students. Often in class, they were uncooperative and surly; they always worked together, never helping other students, and generally disdained the course, instructor, and fellow students. In contrast, there were a couple of students who were very weak in mathematics and filled with math phobia, several who worked very hard and seriously, and several who thoroughly enjoyed every aspect of the class and class learning activities.

Pre-service teachers in MAT 232 display a remarkable disparity in background, interest, and knowledge, and have very divergent needs: middle school mathematics teachers would benefit from much more rigorous mathematical training than that necessary to teach first or second grade.

The College of Education had clearly communicated to me that they would like my pedagogical methods to "model good teaching." In particular, they were very much interested in student-centered learning and hands-on activities. There is a long history of antagonism between CEHD and CAS on obtaining the correct balance between pedagogy and high content standards, and, for me, this tension was my first direct exposure to the differing values between the Departments of Teacher Education and Mathematics, though I had, of course, heard many lament of such problems before.

It is clear to me that these tensions exist all over the country. It is also clear to me that there is no simple solution to them. In a nutshell, for the purposes of discussion and reflection, I outline my understanding of the tensions inherent in teaching any mathematics content course to pre-service elementary teachers below:

(1) Instructors with a background in mathematics generally complain that the students are poorly prepared and have weak skills. Faculty from CEHD argue that the problem is not poor preparation, but poor teaching. Neither side in the argument seems to respect, believe, or find merit in the other viewpoint. This, I believe, stems not from a lack of good will, but instead from a lack of expertise. Teacher educators tend not to have a background in mathematics sufficient to make informed content curricular decisions and

My personal view is that pedagogies are extremely age and content sensitive, and that pedagogies appropriate for high school mathematics students may not be appropriate in a college classroom or in a second grade reading class.

mathematicians tend not to have a background in educational theory sufficient to excite less mathematically inclined students to study geometry.

(2) Colleges of Education want instructors to model good teaching; this tends to mean student-centered learning and activity-oriented classes. However, many mathematics instructors are unaccustomed to such pedagogical methods or perhaps even suspicious of them. My personal view is that pedagogies are extremely age and content sensitive, and that pedagogies appropriate for high school mathematics students may not be appropriate in a college classroom or in a second grade reading class. This has meant that I have found the suggestion to model good teaching to be quite narrow, with an assumption that good teaching is the same for all ages and settings.

(3) Both Departments of Teacher Education and Mathematics neglect mathematics courses for elementary teachers. Generally, it is difficult to find a mathematics faculty member interested in elementary education and there is often a last minute search for an instructor. Mathematics departments do not prize these courses. For different reasons, but with the same outcome, teacher educators may also devalue mathematics content courses. I have witnessed students being advised to take mathematics courses online to fulfill content requirements, and have seen my stated concern over the inadequacy of current mathematics preparation for K-8 teachers dismissed by some involved in the TEAMS program. To be fair, a major deterrent to addressing these problems at USM is a lack of funds and faculty. But this is precisely the rub: while all over the nation many acknowledge the sorry state of pre-service mathematics training, there does not seem to be an institutional or national commitment (in terms of faculty and resources) to work to measurably improve the situation. We are left with the unpleasantness of heated exchanges, incompatible perceptions of the nature of the problems, finger pointing, and demoralization.

(4) Program requirements may encourage grade-consciousness at the expense of interest in learning. TEAMS students must earn at least a grade of C in all required courses to remain in good academic standing. This puts pressure on both student and teacher, particularly if the student struggles with mathematics, and the instructor maintains high standards. In a somewhat parallel situation to what is happening with "high-stakes testing" in the public schools, interest and enjoyment in learning can become less important than satisfactory performance on tests and assessments. Moreover, faculty members may feel pressure to inflate grades, to avoid ruining the prospects of a future teacher.

After much thought and advice seeking, I decided to teach MAT 232 with a strong emphasis on student-directed learning and chose topics that I thought were appropriate for future K-8 teachers based on the recommendations in The Mathematical Education of Teachers (CBMS, 2001). This CBMS manuscript has been the cornerstone of my topic choice since its release.

In a typical class, we would begin by going over homework problems from the previous week and reviewing a bit. Then I would hand students a large packet of materials, worksheets and instructional materials, and we would begin the day's activities. Students were encouraged to work in small groups and present solutions to problems on the board. Many of the activities required constructions with paper, clay, compass, protractor, etc. I tried to select activities that were intriguing, instructional, and appealing to future teachers. The class would end with students summarizing their work and solutions, and the assignment of weekly homework.

One activity that was popular with students was a research and oral presentation project on a topic of interest from geometry. Students selected a topic, researched it, wrote a paper, and then gave an oral presentation to the class. Other students peer-reviewed the presentations. In general, student feedback was extremely positive, though I had mixed feelings about the success of this assessment.

As an illustration, one particular student gave a presentation on the golden ratio using PowerPoint, complete with bells and whistles, which other

students found fantastic. Several students commented that this was the "best of all presentations." This was very distressing to me since, while the formatting was beautiful, the content was plagued by mistakes and misstatements, and, in my mathematical opinion, it was clear that this student had not understood many mathematical points. I felt tongue-tied, stymied, and unable to criticize constructively, since I was the only person in the room who was aware of the mistakes in mathematical content and consequently not impressed with the graphics.

Unfortunately, this student's written work was marred as well by inaccuracies, misspellings, and poor writing. In response to my lengthy written evaluation, the student essentially accused me of disliking her, being unnecessarily harsh, and pointed to all the positive feedback from fellow students as evidence of my unfairness.

Needless to say, I was flummoxed. While this was in no means typical of this class' behavior, it is this incident(s) more than anything else that I have reflected on in rethinking how to teach MAT 232. Perhaps the most significant observation was that this student did not believe that I had anything valuable to offer her. Strangely (to me at least), this sentiment showed up in my teaching evaluations too: students remarked that they already knew enough mathematics to teach and that I did not seem particularly knowledgeable about geometry.

Three years later, in spring 2004, when I got the opportunity to teach MAT 232 again, I completely reworked the curriculum framework for this geometry class. This time the class was to meet twice a week, the book was different, and more direct instruction was worked into daily lessons. I developed my own worksheets for each lesson, incorporated a class portfolio, and integrated computer work and other features into the course. This class was a success.

While the changes I made to course instruction and pedagogies greatly improved the class, I also give credit to the twelve students-they brought to class fantastic attitudes: strong work ethics, enjoyment, questioning minds, and a willingness to help out others. I surveyed the class at the end of the school year, and in response to a question about the significance and importance of learning geometry and MAT 232 in particular, most students wrote that they thought this class was extremely important to their goal of becoming a highly qualified K-8 teacher.

Despite encouragement to move to a more portfolio-based method of assessing student work, I placed a heavy emphasis on traditional testing in assigning final grades, much heavier than during the previous time I taught the class. There were three quizzes throughout the semester and a cumulative final exam. Any quiz score could be erased or replaced with a stellar performance on the final exam, as a means to encourage improvement and as a reward for progress, and a class portfolio, a teaching project, homework, and attendance were all factored into a final grade.

The reason behind this shift in assessment strategy was two-fold. First, I wanted to satisfy myself. At the end of MAT 232 in 2001, I felt as if the students had not internalized geometry in measure with the high grades they earned. They had done good work in projects, homework, and in-class activities, but met with less success in skill and knowledge acquisition. Perhaps my background in mathematics leads me to think this way, but I believe I did not set the bar high enough in terms of students' learning and understanding of geometry, particularly when I envision these students working in their important profession, teaching young people mathematics.

Second, as a result of new state and federal teacher preparation guidelines, pre-service K-8 teachers will be tested to demonstrate mathematics content knowledge. I have many a quibble with such testing, yet I wanted my students to be in the best position to easily pass such requirements.

This time the class was to meet twice a week, the book was different, and more direct instruction was worked into daily lessons. I developed my own worksheets for each lesson, incorporated a class portfolio, and integrated computer work and other features into the course.

Discussion

In conclusion, I would like to explore some ideas and issues in mathematics education that extend beyond the specifics of USM.

Student-Directed Learning

Incorporating the direct instruction model of teaching with the activity-based method made class meetings more coherent and added needed structure.

I have always been an advocate of student-directed learning, and firmly believe that each student is ultimately responsible for his or her learning. As an eager student of new ideas and pedagogies, I was pleased with the opportunity to implement in MAT 232 some of the active-learning methods and hands-on strategies I had learned from the College of Education. Not only was this interesting for me to explore, but it addressed an ongoing concern of CEHD, that mathematics for elementary teacher courses necessarily should model good teaching and current K-12 pedagogies. However, I am now a much more moderate advocate of self-directed learning, as I understood CEHD's philosophy, than I was in 2001.

In the first round of teaching MAT 232, I misjudged the extent to which future teachers would enjoy discovery and open-ended projects, pedagogies encouraged and applauded by many educators. A theme appeared in student evaluations: "The instructor relied too much on our teaching ourselves"; "We had to teach ourselves everything." These comments, together with my dissatisfaction with student progress and my respect for the difficulty of learning mathematics, made me reevaluate self-directed learning.

The model I settled on for MAT 232 in 2004, was a mixture of direct instruction and self-directed learning and, in my opinion, was much more successful. In a typical one and one-half hour lesson, I would hand out a packet of self-designed activities (about five pages). Then, using an overhead projector, I would introduce new ideas—what it means for triangles to be congruent or similar, for example—relying both on worksheets I had created and student questions and input. The students very much steered the class, setting the pace and inducing me to explain more or less, depending on their questions and feedback. If all went as planned, after one-half hour the students were working busily in small groups on the day's activities. At the end of the period, we would summarize what we had learned, and go over problems, often with students presenting solutions at the board.

Best of all, the students enjoyed class and worked hard. In their self-evaluation at the end of the semester, each student responded very positively to working on problems in class and reported that they much preferred this format to a lecture class. They felt that they understood concepts much better, by immediately working problems on new topics. What I have learned is that it is too much to expect pre-service elementary teachers to learn mathematics entirely through worksheets and self-instruction. Incorporating the direct instruction model of teaching with the activity-based method made class meetings more coherent and added needed structure.

Importantly, I am more satisfied with my role in such a class. While I still think it very odd (and inaccurate) that students in the first MAT 232 class thought I did not understand geometry very well, now I am using my expertise in mathematics more wisely. With the direct instruction segment at the beginning of class, I find myself better able to direct students towards correct understanding of concepts and often include interesting tidbits about the history and discovery of geometric ideas.

As a side benefit, classroom dynamics were much more pleasant the second time I taught MAT 232. Morè careful placement of students, better advising, more mature students, changing pedagogy, and class meetings twice a week all contributed to the improved atmosphere.

The Importance of Content

Faculty and students from the College of Education and the College of Arts and Sciences often fail to share views on the importance of mathematical content knowledge. Certainly, they both view content knowledge as essential, but they differ on precisely what strong content knowledge means and how to assess strength in a content area. The source of misunderstanding seems to be a lack of expertise on both sides; what is needed are mathematicians who know education theory and teacher educators who know mathematics.

In my experience, it has been difficult to work through impasses, when education faculty do not

have a fundamental knowledge of mathematics, and mathematics faculty do not have a deep understanding of education. Even when gathered in the same room, it is as if two different languages are spoken. This polyglot atmosphere is amplified, when administrators, experts in neither education nor mathematics, join the fray. The State of Maine traditionally bypassed this discussion by requiring specific courses for certification. With new licensure guidelines no longer specifying curricula, however, the need for better understanding and agreement between Colleges of Education and Arts/Science is more pressing than ever.

Specific Recommendations

As part of the MMSTEC project, in spring 2001 I evaluated the mathematics component of the TEAMS program and wrote a report (Allman, 2001) summarizing my findings. The following recommendations are an extension of those ideas and may be of interest to those working in K-8 pre-service programs.

(1) I have found that there is not enough time in the semester for all the projects I would like to work into the curriculum. Moreover, some student feedback indicated that the class often seemed rushed towards the end of the meeting. My view is that learning mathematics is aided by more frequent class meetings—twice a week is the norm at USM—and that extending the length of instructional time would increase learning, satisfy pedagogical goals for pre-service content courses, and allow sufficient time to cover topics that pre-service teachers should be exposed to in courses like MAT 232.

(2) I recommend two geometry courses for K-8 pre-service teachers, one for those intending to teach middle school and one for early elementary teachers. Although many states group elementary and middle school requirements together for the purposes of certification, there is a vast disparity in the extent of knowledge needed and the background and interest in mathematics of those interested in teaching elementary school and those interested in teaching middle school. Current recommendations (CBMS, 2001) argue that middle school mathematics teachers should be "mathematical experts" and "mathematical thinkers."

(3) Finally, my contention is that one of the most important ways to improve pre-service elementary mathematics education is in the psychological arena. Progress is only possible with communication, regard for differences of opinions, a willingness to compromise and find solutions, and respectful interpersonal interactions. Not only would easier relations between Departments of Teacher Education and Mathematics make advancements and constructive changes come about more quickly, but such positive attitudes would trickle down to students, who could more easily internalize the value judgment, that mathematics education is an important part of their training.

Progress is only possible with communication, regard for differences of opinions, a willingness to compromise and find solutions, and respectful interpersonal interactions.

Elizabeth Allman is Associate Professor of Mathematics at the University of Southern Maine. As an active participant in the MMSTEC grant, she worked for five years with the Teacher Education Department at the University of Southern Maine to help develop an undergraduate secondary mathematics teacher education program at USM. She enjoys mathematics and mathematics teaching at all levels, and has taken pleasure in working with local mathematics teachers and teaching interns in southern Maine.

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Applying Student-Selected Creative Assessments in Physics

Paul G. Caron
Assistant Professor
University of Southern Maine
Lewiston Auburn College
caron@usm.maine.edu

Assessment in this university physics course, serving teacher candidates, moves beyond traditional and standardized testing. The author embraces an assessment approach that relies, in part, on creative assessments to show conceptual understanding.

Introduction

This paper focuses on assessment in a university physics class for non-science majors, including teacher candidates. The current drive to measure student achievement through standardized testing does not mean that all evaluation instruments must be in traditional formats using selected-response items. In this class, students are allowed to use their own learning styles, multiple intelligences, and creativity to demonstrate their attainment of course objectives and standards in a classroom based on discovery and constructivist learning.

Pedagogical Philosophy

Oliver Sacks, the noted neurologist, relates how his love of science, learned from his interactions through his home environment, all but disappeared when forced to sit in classes listening to teachers imparting knowledge to him:

> That calm deep center, my former passion, was no longer there. Adolescence had rushed upon me, like a typhoon, buffeting me with insatiable longings. At school I had left the undemanding classics "side", and moved to the pressured science side instead. I had been spoiled, in a sense, by my two uncles, and the freedom and spontaneity of my apprenticeship. Now, at school, I was forced to sit in classes, to take notes and exams, to use textbooks, that were flat, impersonal, deadly. What had been fun, delight, when I did it in my own way became an aversion, an ordeal, when I had to do it to order. What had been a holy subject for me, full of poetry, was being rendered prosaic, profane. (Sacks, 2001)

I want to make sure that my classroom is not impersonal and deadly. Keeping in mind that all students are naturally curious about science and that each of them can learn, I try to establish a learning environment that is supportive of all students and takes into account their personal goals, experiences, and previous knowledge about science.

The choices I make in preparing my course follow basic beliefs about students. They include:

- Respecting the learning styles and multiple intelligences of the diverse student population.
- Allowing more time to completely understand specific areas of content rather than racing to cover material.
- Transferring learning to problem solving situations that allow students to use their own experiences and creative thinking.
- Promoting personal discovery that takes place after introduction and practice.

The effectiveness of each of these pedagogical ideals is documented and supported by national organizations such as the National Council of Teachers of Mathematics (NCTM, 1989, 1995, 2000), the National Science Teachers Association (NSTA), National Research Council, (1989, 1995), and educational scholars such as Dewey (1916),

Piaget (1973), Vygotsky (1978), and Goodlad (1984). My personal experience and growth through practice have also led me to this way of thinking.

The pedagogy I practice in the classroom provides students with the opportunity to make connections with their personal experience and the physics content. They must learn to think on their own while I facilitate the process. This process leads to creative thinking whereby students demonstrate their attainment of understanding by generating new ideas or objects. The students also use critical thinking skills to evaluate these products throughout the creative process.

Using my philosophy and knowledge as bases in my method choices, I take risks that provide new ways of looking at mathematics and science. Creative thinking in the classroom allows my students to demonstrate their attainment of high levels of understanding, motivates them to look at content areas in different ways, and assists them to construct more meaning in their learning, thus attaining the concepts, principles, and applications in significant ways.

Keeping in mind that all students are naturally curious about science and that each of them can learn, I try to establish a learning environment that is supportive of all students and takes into account their personal goals, experiences, and previous knowledge about science.

Creative Assessments

Formative assessment is important in the discovery classroom, allowing students to continuously demonstrate their attainment of standards and essential knowledge. Creative assessments allow students to use their multiple intelligences to individualize the process of evaluation (Diaz-Lefebvre, 2004). More importantly, the students demonstrate higher levels of learning such as synthesis and evaluation as opposed to memorization (Bloom, B. 1956). Since learning is personal and meaningful, students participate in their assessments continuing the learning process as well (Zemelman, Daniels, and Hyde, 1998).

I begin the creative assessment process by designing measurable objectives, embedded in student-designed formative assessments. The objectives are evaluated within the context of the student's own experience using his or her own preferential intelligence. For example, an objective from my physics class states: "Using any creative medium, the student will accurately demonstrate Newton's three laws of motion." Among other formats, the student has the option to:

- Create and present a physical demonstration.
- Create a work of art, music, poetry, or other form.
- Create a story.
- Create a mathematical problem.

Examples of student work include original songs, web sites, fairy tales, short stories, poetry, mobiles, videotaped presentations, science lesson plans, mathematical problems, karate demonstrations, applied technology projects, and sports performances. In several instances, students involve their families and friends in the process, further enhancing the learning process for the student and other participants.

As the facilitator of the course, I allow the students to be as creative as possible. Yet, as the instructor, I assess the final product using a rubric measuring the objectives previously delineated to the students on the presentation's manifestation of physics not the aesthetic properties.

Student Assessment: Newton's Three Laws of Motion

In the first example, the assessment measured the students' ability to create a demonstration on Newton's Three Laws of Motion.

Newton's Three Laws of Motion

First law: An object, whether at rest or in constant motion, will remain in that state until an external force is applied to it.

Second Law: A force applied to an object will accelerate the object; the acceleration is directly proportional to the force applied.

Third Law: For every force (action) on an object there is an equal an opposite reaction force (action).

A student in the teacher preparation program submitted the following poem to illustrate her understanding of Newton's Laws of Motion and application for younger elementary students.

In the first example, the assessment measured the students' ability to create a demonstration on Newton's Three Laws of Motion.

Dead Cow in the Middle of the Road
By Kimberly Bochtler

Dead cow in the middle of the road
Farmland traffic completely slowed
How did it get there? How did it die?
If someone hit it, where is that guy?
Who can move it? No one knows.
It's got to be moved so traffic can flow.

Farmer A said "I will move it. I'll pull and tug."
Try as he might the cow wouldn't budge.
Farmer B said, "I'll lend a hand."
But they couldn't move it an inch across land
Farmer C, a retired physicist, had to laugh,
"You two would be lucky to move a small calf!"

"Physics can help you to save the day.
An object at rest tends to stay that way.
Newton's First Law speaks of inertia
Exerting force to overcome it, just might hurt ya!
It will take a great force to move this much mass.
Go get a tractor and fill it with gas!"

Back came a farmer with his John Deere
Hooked up the cow, put the tractor in gear
The cow moved slowly and the engine groaned,
"At this acceleration rate, we will never get home.
The force of this tractor just isn't enough
A bigger tractor should have the right stuff!"

The cow accelerated quickly with the bigger force,
Demonstrating Newton's Second Law, of course.
Dead cow now on the side of the road
The story continuing to unfold...

Along comes a car the front all dented
The driver jumps out looking rather demented
"I had to leave and come back-my wife's having a baby
This whole day has been rather crazy!
This cow ran right in front of me.
I hit the brakes, and skidded viscously.
The hood folded toward me as it crinkled and crumbled
The cow mooed madly as she was slammed and then tumbled."

The farmer/physicist said his story was exact in fact.
"The forces oppose each other when two objects interact.
The car hit the cow and the cow hit the car.
Newton's Third Law applies to this part.
It explains the dead cow and the dented hood."
The crowd nodded in agreement as they all understood.

All of a sudden, a gasp of surprise,
The cow started moving and opened her eyes!
She got to her feet, turned to the crowd,
And lifted her head, looking quite proud.
She walked to the field and began grazing,
The whole ordeal absolutely amazing!
The man that had hit her danced as he cried,
"Thank God—she was only mostly dead, she hadn't really died!"

I used the following rubric to evaluate the students' work.

15 points: For a complete demonstration showing full understanding and reference to each of the three laws.

12 points: For a reference to the three laws and eighty percent of the demonstration is clear and correct.

9 points: For a reference to the three laws but information is missing in more than half to sixty percent of the cases.

3 points: A reference to the three laws.

The student received 12 out of 15 points. Her reference to the first law was incomplete, as it did not point out that an object in constant motion will remain in constant motion until an external force is applied to it. She cited the first law and showed a high level of understanding by writing that the farmer knew he needed to apply an outside force to move the cow. For the second and third laws, she again cited them and had the farmers explain why they could or could not perform a certain act. In addition, she created a new work.

Student Assessment: Concept of Rotational Equilibrium

In a second example, submitted by another student as a part of a final, the assessment measured the student's understanding of the concept of rotational equilibrium in which the sum of the counterclockwise torques must be equal in magnitude and opposite in direction to the sum of the clockwise torques acting on a body.

Concept of Rotational Equilibrium:
The sum of the counterclockwise torques must be equal in magnitude and opposite in direction to the sum of the clockwise torques acting on a body.

Part Three of Final: The Concept of Rotational Equilibrium

Sci250 Applied Physics

A shift in center of gravity will result in the body's ability to move or rotate. The movement or rotation of the body is caused by torque. Consequently, balancing and stabilization exercises are a great demonstration of torque and center of gravity. One device in my mind that best describes the concept of rotational equilibrium is a balance board. Balance boards are often used in rehabilitation centers and fitness centers to increase strength in the intrinsic muscle fibers, increase stability, and to regain neurological function.

Balance boards resemble seesaws. The fulcrum is on the bottom of the board placed in the center (some boards allow for the fulcrum to be moved). The top of the board is usually flat and is shaped round, square, or rectangular (I will be mostly talking about the rectangular board). The balance boards work by having the individual stand or placing their hands on the board. When the individual initially steps onto the balance board (with the right foot) right side of the board goes to the floor while the left side goes up into the air (this creates a counterclockwise rotation). As the left foot is placed onto the board the force applied to that side will cause the right side to go up into the air (this creates a clockwise rotation). As both feet are on the board there is a constant shift in the forces from clockwise or counterclockwise to establish equilibrium. The rotational equilibrium will be established when the net torque equals zero, which in this case is when the individual balances the board (torque clockwise = torque counterclockwise). The torque is not only determined by the force of body, but also by the placement of the feet (distance from the fulcrum) (T= f * perpendicular d). Consequently, the placement of the feet will affect the balance of the board, if the feet are close to the fulcrum it will be easier to balance because the feet are closer to the center of gravity. Therefore, if the feet are wider it will be more challenging to balance the board due to the distance of the feet away from the fulcrum. The mass of the individual will also affect the balancing of the board; if the mass is not equally distributed across the board then the individual will find themselves constantly shifting side to side, which, can be related back to the force being applied to the board (f=ma).

Finally, I have found that individuals who are shorter will have a much easier time balancing on the board than a taller person. The reason is due to the placement of the center of gravity; shorter people have a lower center of gravity than taller people. Therefore, to get someone started on one of these boards I have them bend their knees, which causes them to have a lower center of gravity in turn makes them feel successful. As the individual progresses I have them increase their stance height. As the individual successfully completes standing at different heights they will then perform squats, or have then have them stand on one foot and balance over the fulcrum. Overall, I am really excited that I have been able to take the physics information and apply it to exercises that my clients and I perform.

Editor's note: The issue of clockwise and counterclockwise rotation is simply a matter of whether the observer is looking at the balance board from in front or behind the board. Additionally, perpendicular d is the distance from the middle of the balance board to the center of the feet.

In a second example… the assessment measured the student's understanding of the concept of rotational equilibrium in which the sum of the counterclockwise torques must be equal in magnitude and opposite in direction to the sum of the clockwise torques acting on a body.

Not all of the projects meet the stated objectives, nor do the students receive complete credit. However, each contribution is an example of a student taking time to think and make connections between new material and previous experience and knowledge.

I used the following rubric to evaluate the students' work.

25 points: For a complete demonstration showing full understanding and reference to the law.

20 points: For a reference to the law and 75% of the demonstration is clear and correct.

10 points: For a reference to the law but less than 50% of the information is missing.

5 points: A reference to the law.

This is an excellent example since the student presented the equations and conceptual examples to demonstrate her knowledge and complete understanding of the concept. The student presented the idea of a fulcrum as a point of rotation and added Newton's second law ($F = ma$) to help support the reason why torque not only depends on the distance to the fulcrum but the force applied must also be considered. She included photos of patients using the balance board in her original work. For this demonstration, the student received 25 points.

Not all of the projects meet the stated objectives, nor do the students receive complete credit. However, each contribution is an example of a student taking time to think and make connections between new material and previous experience and knowledge.

These types of assessments are part of a larger group used throughout the semester in the course. Other types include traditional tests such as the Force Concept Inventory, traditional problem solving, and short answer questions. Students find it beneficial to have an assortment of assessment tools to measure their learning. They do comment on how challenging the process of creativity is, but believe that they have a firm grasp of the content and can apply it in several ways, including traditional tests. Students who go on to fields such as teaching or occupational therapy state that they are able to apply their understanding and make new connections to their fields.

Conclusion

The type of classroom described facilitates discovery and creativity. There is less of an emphasis on the textbook or the lecture. Rather, the student is actively engaged in his or her own learning. Further, the student is actively involved in the assessment process demonstrating higher order learning. The student and I collaborate in developing goals and objectives. We work together in achieving these goals.

In terms of preparing future teachers of mathematics and science, college and university faculty should heed the calls for changes by the National Council of Teachers of Mathematics and National Science Teachers Association to promote reasonable course development. "Prospective and practicing teachers must take science courses in which they learn science through inquiry, having the same opportunities as their students will have to develop understanding" (1995, p. 60). In addition, "The science program should be coordinated with the mathematics program to enhance student use and understanding of mathematics in the study of science and to improve student understanding of mathematics" (1995, p. 214).

The process of implementing creativity in learning and assessing mathematics and science results in knowledge that is authentic, formative, meaningful, personal, and active. Students construct their own understanding of the principles to provide

further impetus for developing future comprehension of new knowledge. This process supports the student's quest to integrate new experiences, relationships, and information in intelligible ways. It values the students' points of view and attempts to encourage students in the directions they have charted for themselves (Brooks and Brooks, 1999).

If we truly believe that all children and students can learn, then we must offer them a rich and meaningful learning experience—particularly those college and university students who will become elementary and secondary mathematics and science teachers. Through creative learning and assessment, we can promote a culture of science literacy.

Paul G. Caron is an Assistant Professor at the University of Southern Maine, Lewiston-Auburn College. He teaches mathematics and physics and is an instructor in the Collaborative Learning And School Success Professional Development School (CLASS PDS) teacher development program. His research focus is developing authentic and alternative types of assessment based on student creativity and multiple intelligence.

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Peer-Led Team Learning in Calculus

Paula Drewniany
Lecturer
University of Maine
Department of Mathematics & Statistics
drewniany@math.umaine.edu

Sue McGarry
Lecturer
University of Maine
Department of Mathematics & Statistics
mcgarry@math.umaine.edu

Jen Tyne
Lecturer
University of Maine
Department of Mathematics & Statistics
tyne@math.umaine.edu

The Peer-Led Team Learning (PLTL) approach is not widespread in mathematics but its aim of providing student leaders, students in a course and instructors with an active avenue of interaction is worth pursuing. This paper describes the author's attempts to bring the PLTL approach to some of their Calculus I classes at the University of Maine. The experience of the student leaders has been incredibly positive and the experience of the students has shown positive aspects but there remains much to assess in that area.

Introduction

In 2002, the three of us learned about the Peer-Led Team Learning (PLTL) model and began discussing how we could incorporate it into mathematics classes at the University of Maine. As we discussed the advantages of such a model, Paula recounted her memories of calculus in high school:

> The only memory I have from high school calculus, after my teacher's name and the fact that there were six girls and six boys in the class, is how I used to telephone my friends to ask if they understood the ideas, like the epsilon-delta proofs that Miss Burbeck had showed us. The on-going joke was that it was all Greek to us! But, we picked each other's brains and learned as we laughed. Looking back, I realize that the lessons of those phone calls were three-fold. First, we talked about mathematics together (and laughed) and I think that, in and of itself, it was good. Second, our conversation let us know we were not alone in our struggles. And third, we had the opportunity to pool our ideas during our conversations, take the time to think about those ideas between conversations, and then talk again to say, "I got it!" or to continue to struggle together.

PLTL formalizes this experience for our Calculus students with structures called workshops providing a small peer group experience. The peer leader guides the learning while encouraging the group members to tap into the support of their peers. Starting in spring 2004, we implemented the PLTL model into two sections of Calculus at the University of Maine, providing a formal setting for small group learning.

Background

Nationally, PLTL started in 1995 with funding from The National Science Foundation (NSF) with the goal of improving the teaching and learning of Chemistry. Since then it has spread to other disciplines including biology, physics, earth science and mathematics. This model is now being implemented at over 75 institutions (www.pltl.org).

Across disciplines there are common critical components for the PLTL model:

- PLTL workshops must be integral to the course.
- Faculty members who teach the course are also involved with the workshops and the peer leaders. Peer leaders are students who have successfully completed the course and are trained and supervised so that they are knowledgeable about workshop problems, learning strategies, and leading small groups.

- Workshop materials are challenging at the appropriate level, encouraging active and collaborative learning.
- Necessary organizational arrangements—including among other things size of group, space, and time—are accommodated.
- The institution must provide appropriate support for innovative teaching, providing sufficient logistical and financial support (Gosser, 2001).

In the fall of 2000, the Chemistry Department at the University of Maine secured NSF support for testing the PLTL approach in its introductory course. After implementing PLTL in a limited number of sections, PLTL now impacts over 800 students per year in two introductory Chemistry courses. Physics, after using small group learning for a number of years in a similar setting, received funding to start PLTL in its introductory courses in the fall of 2001.

After hearing about the experiences of the Physics and Chemistry Departments, in early 2002 the three of us started discussing how we could implement PLTL in our mathematics classrooms. In July 2003 we traveled to City University of New York for a PLTL conference that focused on mathematics. We also applied for a Workshop Project Associate (WPA) grant through the national PLTL office, and in the fall of 2003 we received funding to implement PLTL in two sections of Calculus I for two semesters. With two departments on our campus already using the PLTL approach, we had the benefit of sharing ideas with colleagues further along in their own PLTL experiences. In addition, some of our students were aware of, and some had actual experience with, PLTL.

PLTL in Calculus

Our goals in implementing PLTL in Calculus I were threefold:

- To improve student comprehension of mathematics so students can successfully solve both routine and non-routine problems.
- To improve student attitudes about mathematics.
- To provide an alternative way of learning.

As well as helping students learn calculus, we hoped that PLTL might encourage students to consider a career in teaching.

After deciding that PLTL could be an excellent approach to achieve these goals, the natural next step was to decide in which course the experiment should start. We applied for the grant to help us implement PLTL in Calculus I (MAT126) for several reasons. First, there are a small number of core concepts in Calculus I. Second, there is a large pool of potentially strong leaders in Calculus I—majors in mathematics, engineering, the sciences and secondary education. This leader pool contains students with a sincere interest in the course material. Lastly, some of the efforts in calculus reform dovetail well with the PLTL goals.

The choice of Calculus I also seemed appropriate given its history and its current state of flux in our mathematics department. For twenty or so years ago, calculus courses were large lectures. In the last 10 years, sections have been smaller, about 40 students per section. Yet, the cycle is beginning again. Financial considerations are prompting the department to offer some 80-student sections with weekly TA recitations.

The NSF funds received by the Mathematics Department supported two sections of Calculus I in the spring of 2003 and two sections in the fall of 2004. In spring 2005, we continued PLTL in two sections with funds from Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC). The sections are structured as four-credit courses with three 50-minute classes with an instructor and one 75-minute PLTL session each week. The weekly PLTL sessions are used for nine PLTL workshops with a PLTL leader and four in-class exams.

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Workshops

As we began creating workshops, we realized that the types of workshops we wanted to create fell into one of three categories. First, some of the workshops are discovery workshops. These occur before discussion of a concept occurs in class, with the goal that student learning be enhanced through discovering an idea with peers. Second, some of the workshops are exploratory, occurring after a concept is discussed in class. In these, students explore concepts in more depth with the goal being to deepen student understanding of the idea. Lastly, we created review workshops so students can just practice skills. Sample topics include velocities studied in a pre-lecture workshop using data from an actual car trip made by Sue, surge functions used to model nicotine and blood alcohol concentrations in a post-lecture workshop, and a Jeopardy-like game in which students practiced taking derivatives in a review workshop.

Not only were the workshops polished before they were given to the students, but the peer leaders realized that their input was valuable in creating better workshops.

Knowing of few PLTL Calculus workshops already written as most of the PLTL work in mathematics has been at the algebra level, we wrote all of the workshops we used in the PLTL sections, taking some of our ideas from calculus reform materials. As we waited to hear about funding in the fall of 2003, we began to set up a schedule of workshop topics with possible problem ideas for each topic. We also coordinated our class schedules so that both sections would stay together and therefore be ready for the same workshop at the same time. Once we received notification of funding in the late fall, we coordinated the logistics of hours, classrooms and leader selection, and began planning for the leader training.

Peer Leaders

To identify potential peer leaders, faculty members in the Mathematics Department were asked to submit names of undergraduate students who had recently completed Calculus I successfully. We were looking for students who faculty believed had the calculus skills and the leadership abilities to be good peer leaders. These students were contacted, and if interested, were invited to attend an informational meeting and to apply to become leaders. Based on the applications, eight peer leaders were chosen, four for each section of 40 students.

Training and support for the peer leaders were of prime importance. Throughout the semester, we conducted weekly leader-training sessions. Each two-hour session followed the same basic format. First, the previous week's workshop was discussed so that leaders could share successful strategies, get suggestions for dealing with difficult situations, and report on any changes they thought needed to be made to improve the workshop for the following semester. Next, during the first half of the semester, leaders were asked to read chapters in Peer-Led Team Learning: A Handbook for Team Leaders (Roth, Goldstein and Marcus, 2001) and the readings were discussed. This was particularly important for the peer leaders who had little experience leading groups and those who had never thought of teaching as a career. Lastly, time was dedicated to work through the next week's workshops with one of the instructors acting as a peer leader, while the peer leaders acted as first-time calculus students. This proved to be an excellent way for the peer leaders to determine what they knew and what they had forgotten, and to identify potential problems for their own students. At these weekly training sessions, we also discussed different approaches to facilitating the workshop such as round robin or small groups and decided which would work best for the given workshop. In addition, it was an excellent opportunity for the leaders to discover and discuss how different students might solve the same problem. Another benefit of this role modeling was that the workshops, after this dress rehearsal, could be revised based on suggestions from the student leaders and difficulties that they encountered. Not only were the workshops polished before they were given to the students, but the peer leaders realized that their input was valuable in creating better workshops.

As well as attending the weekly training sessions, leading the PLTL workshops once a week, and completing some outside reading in the Handbook, leaders were asked to write journal entries after each PLTL session describing the session. Entries were sent to us electronically. Comments varied considerably with statements

about the general reception of the workshop, its length and level of difficulty, comments about the approach used in doing the workshop and its success, and questions about how to deal with a particular aspect of the group dynamic.

Individual leaders facilitated the weekly workshops. Working in separate rooms, each group consisted of 8-10 students whose group membership usually stayed the same for the semester. The leaders' goal was to actively engage students in the group with the workshop problems and with each other. Individual leaders endeavored to set a tone so that all students believed they could be part of a free flow of ideas. Leaders learned to configure the group differently depending on the topic of the week's problem, the level of challenge of the week's problem or depending on attendance. Trying to offer timely assistance when a group was stuck, leaders often asked questions of the group so that the group still did the solving. And, leaders always tried to encourage students.

Minor duties of the peer leaders included taking attendance at the beginning and end of each session. Leaders also assigned students up to three points per week, one point for being present at the beginning of the session, one point for being present at the end, and one point for participation. No homework was assigned and no grade for "success" was given. Individual instructors decided the way in which these points would be incorporated into students' course grades.

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Preliminary Assessment

When we began the project, we outlined the following five assessment components to measure the effectiveness of PLTL on student attitudes towards, and learning in, Calculus:

1. The Mathematical Disposition Survey (MDS), a 31 question Likert survey (agree-disagree) that we administered at the very beginning of the first day of classes and again during the last week of classes. The MDS, developed in the Mathematics Department at the University of Maine (Donovan and Beveridge, 2004) and based on the Maryland Physics Expectation Survey (MPEX) (Redish, Saul, Steinberg, 1996), was developed to measure students' attitudes in mathematics courses;
2. The Student Assessment of Learning Gains (SALG) On-Line Survey, an instrument designed for instructors from all disciplines who wish to learn more about how students evaluate various course elements in terms of how much they have gained from them (http://www.wcer.wisc.edu/salgains/instructor/SALGains.asp);
3. Two common final exams questions given to PLTL and non-PLTL sections;
4. A comparison of student grades in the PLTL and non-PLTL section of the course; and
5. Qualitative feedback from the Peer Leaders.

We have examined these assessments for the first two semesters of our project (spring 2004 and fall 2004) and plan to incorporate spring 2005 data later this summer. In summary, the results to date are as follows:

- For the MDS, we examined the change in the average response for each of the thirty-one questions on the survey. In the spring 2004, four of the 31 statements showed significant differences in student response from the beginning of the semester to the end (as measured by at least two standard errors away from the mean response change); in the fall 2004, three of the 31 statements showed differences. We postpone, however, making any conclusions until we examine data from additional semesters.
- Results from the SALG (the student on-line survey) for spring 2004 showed that 95% of the students believe that the workshops helped them understand the main concepts in calculus and about half the students indicate that the workshops helped them a great deal or a fair amount. Students did not complete the SALG in fall 2004.
- On the first final exam question, which involved differentiation of a function that included non-numeric constants, there was no difference in the performance between PLTL and non-PLTL students in spring 2004 or fall 2004.

With most Calculus I students in their first year at University, it also provided an environment where the creation of bonds among a group of peers was possible.

- The second common final exam question involved students using a graphical representation of a function along with the fundamental theorem of calculus to solve a problem. In spring 2004, the PLTL students averaged 3.5 on a 5-point scale and non-PLTL students averaged 2.5. Sixty percent of the PLTL students and forty percent of non-PLTL students achieved a perfect score of 5 on question two. In fall 2004 the PLTL students averaged 3.68 on question two, and the non-PLTL students averaged 4.04.
- The percentage of "non-passing" students (those who received an F, stopped attending, or withdrew from the course after the first third of the semester) in the PLTL sections in the spring was 17% (13 out of 75), while the non-PLTL section was 20% (22 out of 111). In the fall, 14% (10 out of 73) of the PLTL students did not pass, while 20% (61 out of 312) of the non-PLTL students did not pass. In the future, comparisons of grades will be made controlling for SAT score, GPA, major and other factors.
- Our fifth assessment was qualitative feedback from our leaders. Since encouraging careers in teaching is one of our goals of the project, we asked the leaders the following question. "Have your experiences as a PLTL leader led you to think about a career in education? Or, if you were already considering a career in education, have your PLTL experiences strengthened your commitment?" Five of the eight leaders in the spring of 2004 had already been considering teaching and felt that this experience strengthened their commitment. One of the leaders had not previously thought about a teaching career but is now. The leaders were asked to describe briefly their overall experiences with the weekly leader training sessions. Jen, a bio-engineering major, found the training sessions "extremely helpful" and "felt so comfortable conversing and challenging my fellow PLTL leaders." Steve, who hopes for an engineering career, described the workshops as, "Always fun!" and wrote that, "...we worked through the workshops most of the time, which some would call boring, [but] we seemed to always get some laughs." Brigham wrote that he had "...never been in a situation where discussing math was a cool thing." He thought the training sessions were "Awesome." and found that "It's actually a struggle for me to not teach/lead again [in the fall of 2004] primarily because I will miss the training sessions." When asked to describe briefly their overall experience as a PLTL leader, responses were equally positive. Bill, a mathematics major, "I really can't express how fun it's been for me to lead the group." Brigham found the experience "Deepening." and wrote, "For me personally, it allowed me to be geeky, it forced me to find explanations. This caused me to look for underlying theories. I wish I could do it again." For Steve, "It was awesome! I definitely made some friends from my PLTL group and from our leader trainings." And, Sara, who has yet to declare a major, thought the overall experience was "excellent.... Even though I was frustrated at points, I found the experience educational and fun."

Our Reflections

Although the assessment is incomplete, we feel the experiment has been worth the effort. First, students in the groups experienced a different way of learning with their peers leading them to actively learn the material. Some student attitudes toward mathematics changed significantly, as seen by the results of the MDS. With most Calculus I students in their first year at University, it also provided an environment where the creation of bonds among a group of peers was possible. Reflecting on MMSTEC's "Attributes of an Effective Classroom", we feel we are closer to reaching the first two attributes, specifically, that "all students are engaged in learning" and "classes are communities of learners".

Second, the peer leaders definitely had an excellent experience. They solidified their knowledge of calculus and learned how differently students can think about problems. They experienced some of the satisfactions of teaching, strengthened their leadership skills, and had a place to have fun with mathematics, as well as earn some money. New bonds formed among the group of peer leaders and

the faculty and peer leaders worked as a team and all enjoyed it. (A couple of peer leaders commented that the leader training sessions were the highlight of their week.)

Third, the three of us enjoyed the weekly leader trainings, welcoming the opportunity to meet with a small group of talented and motivated leaders each week (a change from our 40-80 student classes). And, we worked together in writing some excellent workshops, which may be published separately—collaborative work all around!

While these results are encouraging and satisfying, we do want to mention the loss of time with our students. Instead of the standard four lecture meetings per week, our sections only meet together three days per week, as the fourth meeting is used for the workshop sessions. We have found it challenging to cover the same amount of material in a reduced amount of time, and we miss the lost time with our students. While we see the benefits of PLTL, we envision meeting four days per week in lecture, and then a fifth day set aside for PLTL workshops. Perhaps this is wishful thinking.

What's Next?

With funds from our department, we will continue PLTL in two sections of Calculus I in the fall of 2005. We are also exploring long-term funding possibilities, including a system-wide proposal for PLTL implementation that was submitted, though funding is not certain at this time. As each semester ends, we will continue to evaluate the five assessment pieces. This will better help us answer the question, "Does PLTL enhance student learning?"

Realizing the benefits of the leader training for both leaders and faculty, we have started discussing how to create a similar avenue for discussing mathematics in the absence of formal PLTL. And, even if PLTL doesn't continue beyond next semester, we will continue to use the workshops we have created in our calculus classrooms.

Conclusion

Although there were few phone calls exchanged, the PLTL experience replicated what was most memorable about Paula's high school calculus experience and, in the process, expanded and formalized it. We—the students within the workshops, the peer leaders with the instructors, and the instructors alone—talked about mathematics together (and laughed) and that was in itself good. We realized we weren't alone in our struggles. And, we pooled our ideas during our conversations, took the time to reflect between conversations, and then talked again to say, "I got it!" or to continue to struggle together!

Paula Drewniany is a lecturer in the Department of Mathematics and Statistics at the University of Maine. She earned her B.A. from Smith College and her Master's from Dartmouth College. She has been teaching mathematics for 24 years, at the high school level for 13 years and at the University of Maine since 1994.

Susan McGarry is a lecturer in the Department of Mathematics and Statistics. She received a B.S. from the University of Massachusetts in Public Health, a B.S. and MS in Civil Engineering, and a CAS in Science Education from the University of Maine. She has been teaching mathematics and engineering for the past 13 years, and is currently on a one-year leave of absence from the University of Maine, while she teaches high school mathematics.

Jennifer Tyne is a lecturer in Department of Mathematics and Statistics at the University of Maine. She has an M.S. in operations research from the University of North Carolina. Her interests include mathematics education and curriculum development.

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My Personal Journey with MMSTEC: Learning Technology for Meaningful Mathematics Teaching

Tandy Del Vecchio

Mathematics Teacher
John Bapst Memorial High School, Bangor, Maine
tdelvecchio@adelphia.net

Technology can play a central role as a learning tool in mathematics. The author has worked with various projects, further exploring the usefulness of technology to bring real world applications and conceptual meaning to her students.

Introduction

I teach at John Bapst Memorial High School in Bangor, Maine. John Bapst is a nonsectarian college preparatory independent high school of 500 students serving over 50 communities in the greater Bangor area. Our school accepts over 85% of its students from towns without high schools. Public funding from the state and these towns then pays the tuition for these students. I have taught all levels of the college preparatory mathematics curriculum including my current teaching assignment, Algebra I, Honors Algebra II, Algebra II, and Advanced Placement Calculus AB.

My change in teaching practices began while completing my Master's degree in Mathematics Education at the University of Maine (UM). Through my participation in two National Science Foundation (NSF) funded summer academies—*Exploring Exemplary High School Mathematics Curricula in July 1997* and *Implementing Change in High School Mathematics* in July 1998—led by Professor Robert Franzosa from the Department of Mathematics and Statistics (UM), I began to look into technology as a learning tool in mathematics. The direction of the new curricula, while new and potentially powerful, was not suited for my school with its solid college preparatory tradition. I did, however, take many ideas from these programs to use in conjunction with, and as an enhancement to, my own teaching. Perhaps the most influential to me was the use of technology for the mathematics classroom. My department incorporated Texas Instrument graphing calculators and Computer-Based Labs into our algebra, pre-calculus and calculus courses, and added Geometer's Sketchpad into geometry. I wanted to extend the use of this technology to model real world functions, hoping to find ways to increase the depth and breadth of student understanding that I was seeing with the calculators. I joined the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC) to work again with Professor Franzosa, one of the principal investigators at UM, and to find out more about incorporating technology in the mathematics classroom.

Project Involvement

I have been an active participant in MMSTEC initiatives for the past four years. I have attended six summer and mid-year conferences, and I regularly attend the Cross Tier Teaching Team (CTTT) meetings held throughout the year at the University of Maine (Orono), serving in a role as an "exemplary" teacher in that setting.

My involvement with MMSTEC began with the first summer academy, held at Bates College. There I met many university faculty and in-service and pre-service teachers in science and mathematics from the entire state of Maine. We would serve as the initial community for MMSTEC. The tentativeness that we all felt in a new situation was broken by the dynamic presentations from the outstanding guest speakers. Diane Ebert-May from Michigan State University, Roger Howe from Yale University, and Jose Mestra from University of Massachusetts at Amherst showed us many techniques to effectively teach large groups of mathematics and science students in a lecture hall setting. Diane's use of post-its and large name cards plus small group interaction proved effective for engaging us in the learning process. Jose demonstrated student inquiry-based learning along with interactive calculator programs showing how students could have immediate feedback from the lessons; interactive calculators allow teachers to see the answers from the students as they work through a class demonstration. I have always encouraged student participation and engagement in the classroom and these presenters demonstrated to me that effective participation is possible at the college level as well as the high school.

I wanted to extend the use of this technology to model real world functions, hoping to find ways to increase the depth and breadth of student understanding that I was seeing with the calculators.

Learning Through Technology

At the Bates Summer Academy, I met Lindsay Junkins, an NSF scholar sponsored by the MMSTEC grant. We developed a close mentoring partnership and she later completed her practicum with me in January 2002. She also had a strong interest in technology in the mathematics classroom and we were able to develop several projects together. My goal was to use technology to enhance classroom learning through artistic and visual presentations from the projects. Our technology projects, described below, included Conic Shapes, Linear Programming, and Graph Modeling. In them, the students did not just have mathematics problems worked out but had a presentation of a problem that had real world meaning and, once displayed, showed creativity and ownership. A larger, visual graph corroborated and reinforced the mathematics of the problem. Students then had a better understanding of the application of the data from real world experiences and had created something of their own.

Conic Shapes with a computer-graphing program:

This project is used in the Algebra II classes. Students created a scene using the basic conic shapes of circles, parabolas, ellipses, and hyperbolas. They graphed equations on the computer-graphing program MathGV (www.MathGV.com), pasted into Microsoft Word for color and design. I have used this project successfully for some years. The students have the choice of drawing the design on large graph paper and then recording the equations, or using the computer-graphing program. In this case the conic equations must be expressed in terms of "y", such as the ellipse:

$$\frac{(x+3)^2}{4} + \frac{(y-2)^2}{9} = 1 \quad \text{becomes}$$

$$y = +/- \sqrt{9(1 - (x+3)^2/4)} + 2$$

Our goal was to develop individual action plans that addressed the many responsibilities identified in the MMSTEC framework. I chose to explore ways that technology can be used as a tool to enhance learning in team member's courses.

Solving for y is a more difficult form of the general equation of the ellipse. The advantage for doing this on the computer is that once the equation is graphed, it is easy to translate and especially useful for reinforcing transformation rules. The students who take the time to try the computer project definitely have a better sense of the relationships to the parameters in the equations.

This year, I ran out of time to thoroughly teach this unit so I relied on the students to learn the shapes from the project. I gave them a survey to fill out at the end and all of them felt that the project was great and a wise use of class time, but they still wanted direct instruction.

> The project helped, but it doesn't stick in my head for long. A longer amount of time and more thorough teaching would help.
>
> Yes, making up your own problems and putting them where you need them helped to figure out how they work a bit better.
>
> Doing the project helped somewhat because we learned how to apply these in real life. It gave me the right graph every time so I knew they were all right and I could understand them better.
>
> It helped me see it actually working.
>
> It did help me understand conic equations because we used and saw real-life examples of these equations. I'm a visual person! It helped me to better understand the computer but it also helped me to see the shapes of the conics.

Linear Programming in Business

This project is used in the Algebra II classes. Again, the students used MathGV to create the graphs and feasibility region pasted into Word to complete to create tables and report the maximum revenue or minimum cost associated with the problem.

Excel or MathGV for function graph modeling in all classes

In Calculus, each student chose a business then found current sales figures and developed graphs of the business and the first/second derivative. They presented this with an analysis of the first and second derivative and sales. The visual benefit of the larger graph and the colorful display added to their understanding of the problem.

Continued Professional Development

Lindsay and I received a mini-grant from the UM CTTT to complete our work on the function graph-modeling project. We presented a summary of the project at a spring 2002 CTTT meeting. Lindsay also included the work in her senior presentation portfolio, and I presented our project entitled: "Technology Applications in Mathematics" at the Association of Teachers of Mathematics in Maine (ATOMIM) fall 2002 conference. I am very grateful for Lindsay's help with the technology and for the relationship we developed. Her ability to use computer projects in the classroom added to her practicum experience and helped her to gain the confidence she needed to present and teach the curriculum. Pre-service teachers will be better teachers if they can use technology in the classroom as a way to engage their students while they become more confident with the mathematics curriculum. Lindsay is currently teaching high school in Baltimore, Maryland. She wrote recently and stated that her principal remarked on the thoroughness of her training. We both benefited from our time together.

The Cross Tier Teaching Team (CTTT) meetings at UM began as a sustained cohort group including University of Maine principal investigators and faculty, "exemplary" and "novice" middle and high school mathematics and science teachers, and pre-service middle and secondary mathematics and science NSF scholars. Our goal was to develop individual action plans that addressed the many responsibilities identified in the MMSTEC framework. I chose to explore ways that technology can be used as a tool to enhance learning in team member's courses.

In one of our earlier meetings, Professor Franzosa shared his course on real world applications with graph modeling. The course involved collecting data and fitting it to linear and quadratic models using the Microsoft Excel spreadsheet program or Key Curriculum software called Fathom. I adapted this to my high school College Mathematics course.

This senior level mathematics course is offered for historically apprehensive mathematics students who have completed Algebra II. I chose to use Excel as my technology. My seniors thought that this unit was very worthwhile. I expanded the unit to include other models including polynomial and exponential functions.

One of the most significant projects we conducted was an AIDS study. The students researched the current data on numbers of deaths per year in the United States and England and then modeled the data using Excel. The exponential model, which seems most likely, is actually not a good fit. The cubic regression model worked the best. The students then presented this project, along with a detailed analysis of their findings, to the Board of Trustees at my school. These students were nervous but proud of their accomplishments and presented with a new sense of confidence in mathematics.

The unit on modeling with Excel and relating to real world situations gave my students a chance to write about the graphs that they developed, providing them with insights they would not have had without this exploration. Later in the course, we did a unit on business profits and curve fitting. Again, their presentations showed that they could speak in a more precise manner with the technical language related to maximum and minimum profit and sales figures. I also use this with my Calculus course where the concentration is on the first and second derivatives and rates of change. They speak more about the mathematics of calculus and less about relating it to the business to be analyzed. I think that the more timid mathematics students definitely benefited from the graph-modeling unit as they developed more precision in language but were not overwhelmed by the mathematics.

As an invited panel participant at the UM Fall Future Teacher's Club dinner, I continued my involvement with pre-service education majors. Specifically, I addressed many concerns that new teachers find in the first few years of teaching. I tried to encourage students to major in their discipline to gain the depth needed for understanding before beginning teaching.

At the second summer Academy at Bowdoin College, a workshop sponsored by Texas Instruments presented new ways to use Statistics in the classroom. Last summer I participated in the Assessment workshop by Julie Liebarkin from Ohio University where my colleagues and I developed a Computer-Based Lab (CBL) to use as a local assessment for the Maine Learning Results. I tested this unit out this fall (while being videotaped) and found it to be useful for demonstrating the quadratic equation with the motion detector. I have used the CBL's motion detectors previously, but found them cumbersome and not always reliable to use. This activity was adequate to provide the students with another way to connect with the mathematics around them and we were able to develop a rubric for assessing the unit.

The influence of my involvement with CTTT came from the comradeship that developed between all of us as educators as well as the willingness to share ideas.

Personal Instructional Changes

The changes I have made in my teaching practices appear to have produced an increased level of participation, understanding and creativity in all of my mathematics students and have enabled me to present mathematics as part of the real world experience for our young people. The influence of my involvement with CTTT came from the comradeship that developed between all of us as educators as well as the willingness to share ideas. In particular, I was encouraged to know that the university faculty members were striving to take a new direction in their own teaching of mathematics. I was able to see and share in the new courses that they were offering to their students. At the last Academy, I helped critique one of the peer-led Calculus labs. It is this type of trust and sharing that has been the most beneficial personal outcome of my involvement with CTTT and MMSTEC.

What have students gained from their work with technology in the classroom? The evidence I have gathered to date includes the following observations:

- College mathematics students presented a mathematics project to the Board of Trustees showing command of the subject and a willingness to present.
- Students, especially the freshmen who I introduced to the Laptops, eagerly seek technology out as a useful tool for learning graphing. I'm not hearing as much of "I can't work on computers".

- Students show knowledge through the creativity and written analysis that comes from the projects, not just mathematical tests.
- One of my hesitant mathematics students keeps telling me about the new TV show: Numbers. She loves it, and recognized many of the concepts that we covered this year, including an ellipse right from our conics project.

Technology in the mathematics classroom is still evolving as the technology companies develop more useful ways to use it in our classrooms. In my opinion, technology will not replace a rigorous course led by a dynamic and knowledgeable instructor, but it will bring ownership and enhanced understanding to the student. Technology can bridge the gap between the different levels of understanding. It even gives instructors a chance to step back and see how the world looks to all of their students. We can both gain knowledge from this as the computer culture changes the way we see the world.

My new goals include more classroom technology, especially in light of the Maine Learning Technology Initiative (MLTI) that has brought laptop computers to every middle school student in Maine. The MLTI means that more and more high schools will be using laptops in the classroom and that students will arrive prepared with the knowledge to use them. I look forward to developing well-designed lessons using technology and mathematics. My participation with MMSTEC has been an invaluable partnership with the greater mathematics community including university faculty and in-service and pre-service teachers. I enjoy mentoring new teachers, and I equally enjoy teaching mathematics in a stimulating and creative environment. I hope to continue collaborating with others and to have an opportunity to take a leadership role in mathematics education for the future.

Tandy Del Vecchio is a high school teacher at John Bapst Memorial High School in Bangor Maine. She has taught at all levels of the college preparatory mathematics curriculum including her current teaching assignment, Algebra I, Honors Algebra II, Algebra II, and Advanced Placement Calculus AB. She holds bachelor's degrees in Philosophy (University of California, Berkeley) and Mathematics (University of Washington), and a master's degree in secondary mathematics curriculum (University of Maine); she has been teaching for 20 years.

Evolution of a Science Instructor: Incorporating Formative Assessment

Grace Eason
Assistant Professor of Science/Science Education
University of Maine, Farmington
geason@maine.edu

Educational research in the form of classroom assessment shows the importance of students reflecting on their own learning, providing instructors with the feedback they need to continually modify and improve their instruction (Cross, 1998). This paper will discuss the use of an on-line tool for undergraduate non-science majors in biology. The Diagnostic Learning Log (DLL) (Angelo & Cross, 1993) is an assessment tool that has encouraged the author's students to reflect on their own learning while helping her improve her teaching. The DLL provides an instructor with in-depth information and insight into students' thinking skills and their awareness of their own learning. This instrument also allows students to document, diagnose, and determine a course of action to better their learning in specific classes.

Introduction

Educational research on classroom assessment suggests that students need to reflect on their own learning, and provide instructors with the feedback they need to continually modify and improve their instruction (Cross, 1998). Because I believe that good teaching will emerge when an instructor takes the time to meaningfully reflect on his or her own teaching, I wanted to apply an assessment that would encourage my students to reflect on their own learning. For example, when I emphasize a particular concept, do my students focus their learning on that core concept or do they emphasize something else that they thought was important? Also, I wanted to determine how effective our class discussions actually were. In other words, are the discussions enhancing student learning and is my teaching accomplishing the required results?

Angelo and Cross (1993) developed the Diagnostic Learning Log (DLL) to help faculty answer many of these kinds of questions. The DLL is a focused journal entry where students indicate what they have learned from a particular unit, pose questions, identify aspects of classroom practice they found helpful, and provide suggestions for facilitating their own understanding of the subject matter. The DLL provides an instructor with in-depth information and insight into students' thinking skills and awareness of their own learning, and allows students to document, diagnose, and determine a course of action to better their learning in specific classes.

By using the DLL, instructors can monitor students' thinking and determine how students are making sense of the information they are learning. This instrument also allows faculty to probe that thinking by posing careful questions to challenge students' ideas and using that information to structure future questions, activities, and assessments (Cox-Petersen & Olsen 2002). The key, of course, to monitoring this kind of progress is to convince students that the assignment is meaningful and to provide them with timely feedback so that they realize that their comments are indeed being integrated into the course instruction in real time.

A Modified Instrument Trial

I knew I wanted something more than an end-of-unit exam or to wait until the end of the semester when I would receive my student evaluations.

In the spring of 2004, I piloted the DLL in a course on the foundations of biology, a small-enrollment course specifically designed for first year non-science majors and transfer students (see Table 1).

TABLE 1 STUDENT DEMOGRAPHICS (N=34)

Freshman	32
Sophomore	1
Junior	1
Male	12
Female	22
First Science Course	31
Second Science Course	3

A total of thirty-four students were enrolled in the class during the spring 2004 term. The sample size is relatively small because of the nature of my dual appointment position and faculty load balance

I modified the Angelo and Cross class session DLL entry so that instead of focusing on one class session, I could use it when my students completed a unit of study in biology, in this case, a unit consisting of an integrated biological theme. Specifically, one unit of study encompassed evolution and biodiversity, while another focused on cellular reproduction and genetics.

Summative assessments in the form of exams at the end of a unit are valuable indicators of student achievement, but they should not be the only tools an instructor uses to monitor student learning. I knew I wanted something more than an end-of-unit exam or to wait until the end of the semester when I would receive my student evaluations. At that point, if students were experiencing difficulties with certain aspects of the course, the semester would be over and I would be unable to address them. For that reason, I had students submit DLL entries at the end of each biology unit to encourage them to reflect on their own learning, while ensuring for my own benefit that they had indeed learned the core concepts I was introducing.

In order to monitor student progress efficiently and effectively I decided to post the DLL questions on my Blackboard site under the discussion section. This provides students with a medium with which they could conveniently log on and post their responses without trying to keep track of individual papers. The other benefit of posting this instrument on-line is that it creates a forum in which students could interact both with me and with each other while discussing the content of the course. "Interaction with a teacher is often an important component of a formal learning experience. However, since both formal and informal learning can result from interaction between and amongst students alone, or as result of interaction between student and content, the participation of a teacher cannot be a defining feature of an educational interaction" (Anderson, 2003).

Before I tried this instrument I was concerned that my students might find the technology to be more of a hindrance than a help in this process. As pointed out by Peters (2001), "As distance education becomes more popular, and as traditional courses require more online assignments, teachers must consider student perceptions of online learning. While many professors and teachers embrace this technology, many students experience confusion and frustration." In order to address this potential issue, I provided students with the opportunity to post a "mock" DLL entry while I was with them during their lab time. This allowed students to become familiar with the technology and the format of the DLL. During this lab time, students also had the opportunity to work together to overcome any technology barriers and to ask me any questions and/or to express concerns they had regarding the DLL.

Students had to complete three DLL entries for the entire semester, and post their entries approximately five days before our next class meeting. This additional time allowed me to read all entries thoroughly and provided the feedback I needed to modify my instruction to create a

meaningful review session. One DLL entry consisted of completed responses to all four DLL questions (see Figure 1, Appendix 1). Students were given ten points for each DLL entry for a numerical grade. The three entries for the semester totaled approximately eight percent of their overall grade.

The instrument addressed four main instructional goals: DLL Question #1 illustrated information my students found to be important and, in the process, allowed me to identify any misconceptions they had. I considered these occurrences as "teachable moments" because often, students would either correct each other when a particular misconception was raised or I would share with the class what the misconception was and then clarify it for them. It is often much more difficult to change the way a student perceives a question, or to help them develop "new ways of seeing things," than to add new knowledge to what a student already has (Driver, 1997). Therefore, I consider the learning opportunity presented in question #1 as particularly valuable and, as they are presented, try to share common misconceptions about a topic with my students. As I explain to them, it is important to identify what the misconceptions are and then work together to learn from them.

DLL Question #2 provides an opportunity for students to pose questions outside of class, and to interact with me and with one another. In addition, this question helped create a structured review of the unit we completed. In the past, when I offered class time to review material prior to an exam, students generally came unprepared. Essentially, they did not study the material ahead of time and did not prepare specific questions in advance. The DLL asked students to identify where the gaps were in their understanding of the material by giving them the opportunity to reflect on their own learning. Because students posted the DLL responses ahead of time, I structured my review sessions around those questions. Students realized that I considered this a very important assignment and, because I addressed the questions that they posted, they began asking very specific questions pertaining to the material. Thus, the review sessions were very productive.

DLL Question #3 helps my students monitor their own learning processes by having them identify what their strengths and weaknesses were in learning particular concepts in biology. Since I vary my instruction using a variety of teaching techniques-lecture, discussion, BSCS 5E Model class activities, role playing, and others—students were able to discuss what teaching modality helped them learn the most and why. In doing so, they began to identify specific components in their learning by associating them with a particular teaching strategy. I took class time to discuss some student responses and began to share what research on learning demonstrates about the importance of applying knowledge in different contexts, and the importance of organizing the information that they are learning (i.e., concept mapping). In the process, my teaching techniques become more transparent to students, because by integrating this into my instruction I model my own learning as an instructor in the process.

DLL Question #4 provided students with the opportunity to offer meaningful suggestions for any changes that might help better facilitate their learning of the subject matter, and this feedback enabled me to incorporate fresh, new ideas into my course. A slight shift in classroom practice occurred in the course because students began to realize that I took their suggestions seriously and felt as though they were part of a learning community. Thus, they began to take ownership of their own learning. When this type of learning community becomes established, students feel more comfortable asking questions in class and also asking questions of each other. We began to approach biology as a community of learners where I served as the facilitator of that process, by drawing attention to the community (Palmer, 1998). In the process, students also became aware that in order to learn they must participate in this form of discourse.

When this type of learning community becomes established, students feel more comfortable asking questions in class and also asking questions of each other.

Effectiveness of the Instrument

The DLL provided students with an open doorway to step through on the path towards seeing themselves as engaged in their own leaning. But how effective is this instrument at introducing students to this new way of thinking about their own learning? To answer this question, I created a survey to determine student perceptions of the DLL.

The survey was distributed once students completed all three DLL entries, during the last week of class. There were a total of eight survey questions. Four questions provided student demographic data and four questions provided students' perceptions of the effectiveness of the DLL (see Figure 2).

FIGURE 2

DIAGNOSTIC LOG QUESTIONNAIRE

Part A: For each statement or question below fill in the answer that relates to you.

1. I am a: First-year Sophomore Junior Senior

2. I am a: Male Female

3. This is my ________ college science course

   a. First b. second c. third d. other ________

4. My major is: ____________________

Part B: Below is a series of sentences. Indicate the degree to which you agree or disagree with each sentence.

SA=Strongly Agree A=Agree UN=Uncertain D=Disagree SD=Strongly Disagree

5. The Diagnostic Log helped me to reflect on, and summarize the information that I have learned in biology.

   SA A UN D SD

6. The instructor addressed the questions that I posted, which helped me during the exam reviews.

   SA A UN D SD

7. The diagnostic log helped me to determine my strengths and weaknesses in learning biology.

   SA A UN D SD

8. The instructor modified instruction based on the feedback she received from the diagnostic logs.

   SA A UN D SD

TABLE 2 DLL DATA (N=34)

Survey Question	SA	A	U	D	SD
The DLL helped me to reflect on, and summarize the information that I have learned in biology.	21%	67%	9%	3%	0%
The instructor addressed the questions that I posted, which helped me during the exam reviews.	68%	32%	0%	0%	0%
The DLL helped me to determine my strengths and weaknesses in learning biology.	20%	59%	15%	6%	0%
The instructor modified instruction based on the feedback she received from the diagnostic logs.	76%	24%	0%	0%	0%

Survey results indicated that, overall, students regarded the effectiveness of the DLL positively. Eighty-nine percent of the students agreed that the DLL helped them reflect and summarize the information that they learned in biology. All of the students (100%) indicated that I addressed the questions that they posted, which in turn helped them during exam reviews. Seventy-nine percent of the students indicated that the DLL helped them determine their strengths and weaknesses in biology and all of the students (100%) indicated that I modified my course instruction based on student responses.

Next Steps

The survey results indicated that from a student's perspective the DLL was very effective. As an instructor I found the instrument extremely helpful in guiding my instruction by providing students with a formative assessment tool that permits them to reflect on their own learning. Classroom practice rarely provides an opportunity for students to reflect on their own learning (Mestre & Cocking, 2002). When instructors provide students with an opportunity for reflection, they are empowered to identify where the gaps are in their own learning and, through this process, can begin to critically analyze how their work is progressing.

When instructors provide students with an opportunity for reflection, they are empowered to identify where the gaps are in their own learning and, through this process, can begin to critically analyze how their work is progressing.

When attempting to apply the DLL instrument, it is extremely important for the instructor to effectively communicate the purpose of this instrument with the students. Essentially, by sharing with students that the research on learning suggests a variety of teaching approaches are needed to facilitate their learning, students will better understand why they need to become more actively involved in their own learning rather than simply expecting the instructor to "carry" them through the course. They begin to make an investment in their own academic career.

The DLL has not only transformed the way I teach science, but it has prompted me to go even further into my educational research by sharing my results and my own learning with my science colleagues, and encouraged me to initiate discussions with my colleagues from science and science education about the art of effective teaching. In so doing, we are beginning to create a learning community of our own as we discover the importance of the scholarship of teaching.

Grace Eason is an assistant professor of science and science education at the University of Maine at Farmington. She teaches introductory environmental science and science education methods for future science teachers. For her environmental science students, she believes her responsibilities are to inspire them by making environmental science interesting, relevant, and applicable to their daily lives. In teaching her pre-service teachers, she believes that she must share her passion for the art of teaching science and inspire and guide them to find their own inner natures as teachers.

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APPENDIX

FIGURE 1

Diagnostic Log Question #1

This assignment is extremely important, it helps me to focus on what you need out of this course and it also allows me to determine what changes need to be made for the future. In addition, since this is a discussion forum, I encourage you to review and respond to your classmate's answers. The feedback you receive from your peers may be extremely helpful. Please be honest and be as specific as possible. List the main points you learned from this unit. Provide some examples. (Note: If you feel that you have not learned anything then you must provide a detailed explanation as to WHY you feel that way.)

Diagnostic Log Question #2

Write any questions you need answers to before you can understand the information within this unit of study.

Diagnostic Log Question #3

In learning about the information in this unit, what did you find most helpful (i.e., particular discussion, lecture, class activity, lab, etc.) and why?

Diagnostic Log Question #4

During this unit of study, what suggestions do you have for changes that may facilitate your understanding of the subject matter?

Angelo, T. A., & Cross, K. P. (1993). *Classroom assessment techniques: A handbook for college teachers* (2nd ed.). California: Jossey-Bass, Inc.

Hand-held Technology and Water Quality: Inquiry Strategies for "In-the-field" Instruction

Robert Kuech, Ph.D.
Associate Professor, Science Education
University of Southern Maine
rkuech@usm.maine.edu

This paper reports on the "In-the-Field" inquiry learning activities developed for a pre-service teacher science methods course. The students used hand-held Palm™ technology plus commercially available test kits to determine the water quality of a small stream. The paper discusses how the author developed and modeled "in-the-field" inquiry strategies for the students along with a general discussion of inquiry methods of instruction.

Introduction

As I prepared to rewrite my syllabus for my science methods courses, I reflected on reports from panels of experts from science, mathematics, and technology that recommended a common core of learning for every high school graduate that would meet five key criteria (American Association for the Advancement of Science, 1989):

- ***Utility.*** Will the knowledge or skill significantly enhance long-term employment or educational prospects and personal decision-making?
- ***Social responsibility.*** Will the content help citizens participate intelligently in making social and political decisions?
- ***Intrinsic value of the knowledge.*** Does the content have pervasive cultural or historical significance?
- ***Philosophical value.*** Does the content help individuals ponder the enduring questions of what it means to be human?
- ***Childhood enrichment.*** Will the content enhance the unique experiences and values of childhood?"

This common core of learning forms the basis of what is needed to be scientifically literate in our society. The teacher must use these points to assess the content that would be appropriate for their students to learn as part of their school curriculum. Our new teachers must be scientifically literate if we hope that they will be able to prepare our young people to be scientifically literate citizens when they graduate from high school. Gathering and analyzing environmental data that can contribute to the expanding field of scientific knowledge is the type of meaningful, authentic activity that can promote the literacy in science, math and technology called for by many national organizations and researchers. I decided to combine cutting edge technology, seamlessly incorporated in authentic activities, with sound scientific methods as the central focus of the "In-the-Field" Inquiry Learning project described in this paper.

This project, part of the science methods courses for pre-service teachers at both the secondary and elementary levels, was developed with the help of funding and expertise provided by the MMSTEC grant. "In-the-Field" inquiry learning, the central theme of this project, is a teaching technique that must be presented in a way that makes sense for the multitude of students who have only experienced science activities as a cookbook, repeat-and-confirm type of lesson. In this type of inquiry learning, students are exposed to the process undertaken by scientists interested in answering questions to real-world phenomena. Effective integration of standards-based activities and computing and communications technologies in classrooms offers an unparalleled opportunity to engage students in relevant fieldwork and analysis. These projects provide authentic learning experiences for the pre-service teachers in the Extended Teacher Education Program (ETEP) and Teaching Elementary And Middle School (TEAMS) program at the University of Southern Maine. The "In-the-Field" Inquiry Learning Project will prepare current and future teachers to teach about aquatic environments utilizing innovative computing and communications technologies and science-productivity tools.

In-the-field Inquiry Learning on Water Quality

In this type of inquiry learning, students are exposed to the process undertaken by scientists interested in answering questions to real-world phenomena.

> "Inquiry is in part a state of mind-that of inquisitiveness. Teaching science through inquiry allows students to conceptualize a question and then seek possible explanations that respond to that question." (2000, National Research Council)

It is important for pre-service teachers to experience inquiry learning and instruction firsthand if we expect them to then use this form of pedagogy in their own classrooms. Inquiry instruction has been shown to increase student achievement when compared to more traditional forms of pedagogy (Marx, et al. 2004). In my pre-service science methods classes, I try to recreate the experience of inquiry by taking the students into the field and providing them with only a very basic outline of how they are to answer the question for the day, that is, "What is the quality of the water in the stream that runs past the athletic fields near the edge of campus?" I provide groups of students with testing equipment that can be used to investigate various parameters of water quality and hope that students will begin to ask questions about what constitutes good water quality. I want the students to ask questions as if they were once again young children entering a new environment. The students then gather and analyze data to find an acceptable answer to their question about water quality. They use the evidence gathered to support their conclusion and present this conclusion with its supporting data to the class. As an extension of this activity, each student designs an inquiry-based lesson and presents this to the class for peer critique.

> "As children and as adults, when faced with an unknown situation, we try to determine what is happening and predict what will happen next. We reflect on the world around us by observing, gathering, assembling, and synthesizing information. We develop and use tools to measure and observe as well as to analyze information and create models. We check and re-check what we think will happen and compare results to what we already know. We change our ideas based on what we learn. This complex set of thinking abilities, which helped early humans gather food and escape danger, constitutes the highly developed capacity we refer to as inquiry."(National Research Council, p.6)

INDICATORS OF WATER QUALITY

Chemical Indicators

Information about the concentration of nitrates (NO3), phosphates (PO4), and dissolved oxygen (DO), as well as temperature, turbidity, coliform count, and pH can be collected using commercially available water test kits. The data can then be used to generate the water quality index (WQI) of the stream, river, pond or lake based on these chemical parameters.

Biological Indicators of Water Quality

An important step in determining the water quality of a stream or small body of water is to determine the presence, if any, and variety of aquatic invertebrates, or creatures without a backbone (often referred to as macro-invertebrates). Macro-invertebrates depend on clean, unpolluted water to live in, and if there is pollution entering the system, these organisms are usually the first to disappear. These species are called "Indicator organisms" because their numbers and variety "indicate" the health or quality of the water in which they are found. Using macro-invertebrates to assess water quality is based on the fact that every species has a certain range of physical and chemical conditions in which it can survive. Some organisms can survive in a wide range of conditions and are more tolerant of pollution. Others are very sensitive to changes in conditions and are "intolerant" of pollution. Water quality can be determined by comparing the number of pollution-tolerant organisms with the number of pollution-intolerant species. Remember, though, that pollution tolerant organisms can be found in both polluted and unpolluted waters.

The Hand-held Technology

The "In-the-Field" Inquiry Learning project is an innovative aquatic information-gathering system that includes a hand-held computer, water testing probes, portable keyboard and water test kits. Students use the system to collect data and execute sophisticated and standardized scientific research protocols.

The equipment for each system includes the following:

- One Palm m130
- One portable keyboard to attach to the Palm Pilots. The keyboard facilitates data and text entry in the field.
- One Imagiprobe LC Sensor interface. Each interface is a small, battery-powered cradle that houses a Palm, with two sockets to plug in sensor probes.
- One Imagiprobe pH Sensor unit (Ag-AgCl combination electrode with a range of 0 to 14 pH).
- One Imagiprobe temperature sensor unit. These durable, stainless steel probes can track short-term and long-term measurements between -10 and 110° C (-13 to 230° F), with a relative accuracy of ±1%. The sensors can be used to monitor both exothermic and endothermic reactions, or thermal variations in soil, organic material, and bodies of water.
- One Imagiprobe Dissolved Oxygen (DO) probe. The probe replaces the old chemical kits, enabling fast, accurate measurements of dissolved oxygen concentration [range of 0 to 14 mg/L (ppm)] in water samples. The built-in temperature compensation allows the probe to be calibrated in a lab prior to use in the field.
- One chemical water quality test kit from Carolina Biological.

THE WATER QUALITY ACTIVITIES

The pre-service teachers are divided into collaborative groups of four and escorted to a small stream, previously selected by the instructor. Each group takes with them a set of the hand-held technology, and a clipboard with a pen or pencil.

Activity 1: Narrative Description of Collection Area

The student chosen to be the recorder for the group, finds a comfortable place to sit, and with the help of the rest of the group, uses the keyboard and Palm to record a narrative description of the area they have chosen to make their assessment of water quality. The group must carefully and thoroughly describe the complete riparian zone. This would include the stream itself and the buffer area between the stream and the upland environment that forms the immediate watershed. This narrative should include a qualitative description of the stream itself including the general look of the water, the composition of the bottom, the size and distribution of rocks/pebbles, and any other distinguishing features that might influence the quality of the water in the stream. The description should also include the types and distribution of vegetation in this zone, as well as any man-made additions or disturbances. The student who has been chosen as the recorder would use the keyboard to enter this narrative directly into the Palm while the group is in the field.

Activity 2: Chemical Parameters

The students use the digital probeware and water quality test kits to collect data about the chemical parameters of the water in the area they have chosen. Using the Imagiprobe interface and probes, the students can collect data that is entered directly into the Palm hand-held device, or they can read the information and enter it into an excel spreadsheet using the Palm keyboard. The students collect information about the concentration of nitrates (NO3), phosphates (PO4) and dissolved oxygen (DO), as well as temperature, turbidity, coliform count, and pH. The data can then be used to generate the water quality index (WQI) based on these chemical parameters. The data collection system, provided to each group of students, contains separate test kits for collecting the concentrations of nitrates, phosphates, and dissolved oxygen, as well as the turbidity and coliform bacteria counts. Each kit has a set of explicit directions for the students to follow. Once the data has been collected using one of these kits, students record the information in a spreadsheet on the Palm.

Activity 3: Biological Indicators

The students place a fine-mesh net downstream from where they are standing and then kick or otherwise disturb the bottom of the stream. This dislodges critters that live on or under rocks, allowing them to float downstream into their net. The students carefully remove the net from the stream and place about one inch of water in a white tray and empty the contents of the net into it. The students continue to collect insects until 50 insects are in their tray. Students then use spoons and tweezers to pick up the insects and separate them into groups with

The "In-the-Field" Inquiry Learning project is an innovative aquatic information-gathering system that includes a hand-held computer, water testing probes, portable keyboard and water test kits. Students use the system to collect data and execute sophisticated and standardized scientific research protocols.

similar external characteristics. Then, they use the macro-invertebrate tally sheet (provided in their kits) to help identify the insects, and enter them into a spreadsheet on the Palm. The biotic index (included in the Carolina kit) has a system of points for each group of insects. Students count up the number of insects from each group, and calculate their point value according to the biotic index. Based on their results, the students should be able to determine the relative quality of the water.

Discussion

This type of questioning and facilitating of student work is a critical strategy for teachers to develop, in order to successfully use inquiry-based pedagogy.

For many of the participants in my science methods courses, this activity is their first experience with data collection and analysis using technology of this type and with inquiry methods in the field. They have been used to "cookbook" labs that are meant to just repeat and verify science techniques with little emphasis on the conceptual understanding connected to the laboratory experience. This is also my students' first experience with an activity that simply asks a question and provides the materials for exploration. This is especially true for the K-8 pre-service teachers who generally have a limited preparation in science content. They are at first a little hesitant to undertake the task, but soon are fully engaged in the activity and excited that they could figure out how to conduct an authentic science experiment and seek the answers to their own questions. This is where the instructor helps the process along by asking the students what other types of data they should be collecting, how they might analyze the collected data, and what the data means. The instructor works individually with the students or groups to facilitate understanding of inquiry techniques, data collection and analysis and the interpretation of data. The students are encouraged to think about the other factors that could affect water quality or the alternative answers that could be arrived at using the same data.

During the follow-up activity, when the students write and present their own inquiry-based science activity, they often ask each other what their scientifically oriented question is, and the evidence their students must collect to support the hypothesis. During this activity, the instructor can see how fully developed the students' understanding of inquiry and data analysis has become. Their written lesson plans include questions that promote higher order critical thinking skills of their students. In their previous lesson plans, the questions are more of the fill in the blank type of low-level thinking. When the students present these lessons to the class, they become much more of a facilitator to help assist the groups as they work. This type of questioning and facilitating of student work is a critical strategy for teachers to develop, in order to successfully use inquiry-based pedagogy. The increased ability of my pre-service teachers to facilitate higher order thinking skills after their involvement in the "In the Field" activities and the increased richness of their lesson plan activities, is evidence of how this technique can promote the use of inquiry-based pedagogy. Student comment forms about the course provide further evidence of the effectiveness of this technique as they often contain items about how much they learned from the "In the Field" activities and that now they are excited about teaching science in their own classrooms.

I have learned that my students have benefited greatly from being directly immersed in the activities as if they were high school or elementary students themselves. They seem to enjoy "being a kid again" and experiencing the activity through the eyes of a student. After the course activity they must develop their own activities for their potential students and present this to the class. During this development phase, the students get to deeply reflect on their experience and make sense of the nuances of teaching and learning using inquiry. It is often said that "teachers teach the way they were taught" and if they are taught using inquiry-based strategies, hopefully they will also teach this way.

Dr. Robert Kuech, a former high school science teacher, is an Associate Professor at the University of Southern Maine specializing in teaching science education methods. Dr. Kuech's current research focuses on learner interactions that may promote conceptual understanding in science. He is also interested in how appropriate use of technology can facilitate these conceptual interactions. Dr. Kuech is involved in the Extended Teacher Education Program (ETEP) at the University of Southern Maine, and works actively in their professional development schools, providing leadership in science and technology education.

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Application of NASA Materials to Classroom Use

Patricia Millette
Earth Science Teacher
Mount Blue High School
patti.millette@umaine.edu

The earth science teachers of Mount Blue High School supplemented instruction to prepare students for a common earth science assessment that referenced and used astronomical technology, specifically the electromagnetic spectrum. The author describes the instruction and the benefits to student learning and results on the common assessment.

Introduction

This study focuses on the use of supplementary instruction to prepare students for one of five common assessments required for graduation from Mount Blue High School in Farmington, Maine. The purpose of the study is to determine the effectiveness of providing some instruction regarding the electromagnetic spectrum prior to covering an astronomy unit that is heavily dependent upon knowledge of remote sensing.

Having previously used the common assessment "Black Holes" written as a statewide common assessment (LAD) (http://www.state.me.us/education/lsalt/LAD/science9-12.htm), and finding difficulty with the nature of the assessment, the four earth science instructors at Mount Blue High School altered it to address technology used to study astronomy. Because most of this technology is based on remote sensing, it seemed prudent to address the electromagnetic (EM) spectrum specifically before giving students the technology assessment. The four instructors assumed that students' performance on subsequent assessment would improve after this instruction. They acquired information about a variety of remote-sensing technology from both a summer NASA institute at Goddard Space Center and a NASA workshop sponsored by the Maine Mathematics and Science Teachers Excellence Collaborative (MMSTEC).

Compiling concepts from Benchmarks (1993) and Hewitt (1999), the teachers constructed an 18 item pretest addressing a variety of basic points about the EM spectrum. At the commencement of a unit on astronomy, 62 students took this 18 item pretest (See Appendix A). Following the pretest, students completed several activities to illustrate the nature of visible light as one form of electromagnetic radiation, the behavior of light in various circumstances, the differences between reflection and refraction of light, and how different types of radiation are used in remote-sensing devices. Students went on to research various types of space-related technology as a common assessment (assessments common to all students in all sections with all teachers of that course), and present oral reports pertaining to this technology as a classroom assessment (assessments that are part of an individual teacher's classroom plan).

At the end of the first semester, the same 18 true/false questions were embedded in a primarily multiple choice mid-term exam, and scores were recorded as percentage points in both the pretests and posttests. Fifty-eight of the 62 students who took the pretest remained in the course and subsequently took the posttest; the final analysis includes only these 58 students.

Results

Pretest and posttest scores were analyzed with a dependent sample t-test using SPSS. Descriptive statistics are shown below (See Table 1). The pretest score set had an approximately normal distribution, (See Figure 1), and the posttest score set had a slightly negative skew (See Figure 2). The hypothesis predicted that there would be a change in scores following instruction on the EM spectrum, and a dependent groups t-test (two-tailed) showed that the mean pretest score (M=61.5, SD=11.6) differed significantly from the posttest score (M=75.1, SD=14.4), (n=58, p<.001). Therefore, the hypothesis that students' scores would change after instruction on the EM spectrum is supported.

TABLE 1: PAIRED SAMPLES STATISTICS

		Mean	N	Standard Deviation	Standard Error Mean
Pair 1	Pretest Scores	61.5	58	11.6	1.6
	Posttest Scores	75.1	58	14.4	1.9

FIGURE 1
PERCENT SCORES ON EM SPECTRUM TEST

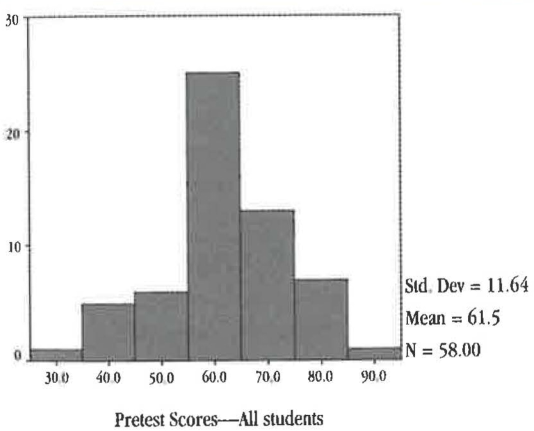
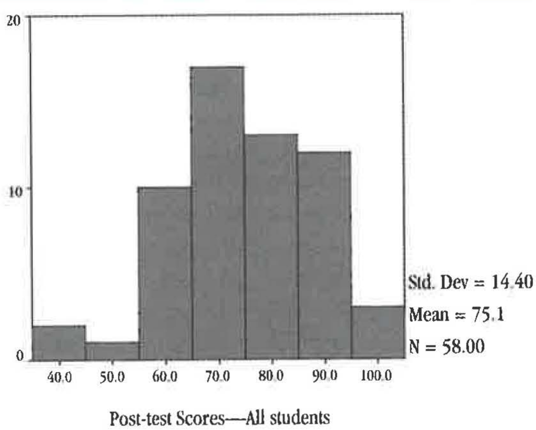


FIGURE 2
PERCENT SCORES ON EM SPECTRUM TEST



Discussion and Conclusion

In addition to simply learning about the spectrum itself, the exciting aspect of this study was that students were able to directly apply their knowledge of the EM spectrum to a collection of astronomical technology…

Overall, most students improved their scores after instruction, with four students keeping the same score and seven showing poorer scores. This evidence shows that it is definitely worth conducting specific instruction pertaining to the EM spectrum instead of simply making random references to it in while teaching other topics that depend on understanding the EM spectrum.

In addition to simply learning about the spectrum itself, the exciting aspect of this study was that students were able to directly apply their knowledge of the EM spectrum to a collection of astronomical technology in a common assessment required of all first year science students. The common assessment known as "Tools in Space" (See Appendix B) had been used in previous years as a more informal activity, with many of the students trying to explain complicated remote-sensing devices while having only a sketchy understanding of how they worked. Although no formal measurements were taken in previous years, all four teachers qualitatively agreed that the students' presentations on this space technology improved with specific instruction on the EM spectrum, and that the additional instruction increased their understanding of the workings of remote-sensing technology. They were obviously more engaged in the assessment itself, showed a deeper understanding of how the technology works, and exhibited considerably more confidence in the oral presentations than in previous years. As a result, it is possible to infer that having direct instruction on the EM spectrum will positively affect student performance on this common assessment, and in turn increase their chances for graduation, especially if their remaining common assessment scores are borderline scores.

We realize that the results of the test are not completely definitive. Before future testing of this material, the questions will probably change from a true/false format to a multiple-choice or short-answer format. This will decrease the probability that students are arriving at correct answers solely by chance.

Furthermore, since this experiment was the first attempt at the organized instruction of this particular concept, and much of the instructional pedagogy was experimental, results of this test may show more pronounced results with more instructional experience and some additional classroom materials and activities. These might possibly include having actual spectroscopes on hand for students to use, displaying a large poster of the EM spectrum to help students visualize the concepts of waves, experimenting with a series of lenses and mirrors, and/or doing a "flame test" demonstration to show that the types of materials burned affect a spectrum. We are encouraged by our preliminary results and anticipate even greater impact on student learning with these continuing efforts.

Patti Millette is a veteran earth science teacher at Mount Blue High School in Farmington Maine. She has an M.Ed. in Science Education, an M.S. in Geology from the University of Maine, and is currently working on an interdisciplinary Ph.D. program in Geology and Science Education. Due to the lack of good qualified earth science teachers, she has developed an interest in teacher recruitment and retention issues.

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APPENDIX A

Questions, answers, and notes to pretest and posttest

1. Radiation is different than light.
   A: False. Light IS radiation.
2. Sound waves and radio waves are the same thing.
   A: False. They are both waves, but sound waves are vibrations through a medium. Radio waves are electromagnetic radiation, and need no medium.
3. Light is fundamentally the same as microwaves, radio waves, and x-rays.
   A: True. Microwaves, radio waves, x-rays, and visible light all represent different wavelengths of the EM spectrum
4. Light passes through materials in the same way that a bullet passes through an object.
   A: False. They don't make holes in objects.(This question will be omitted. It is too ambiguous and not very useful in this context).
5. White and black are colors.
   A: False. White light is a combination of all the "colors" in the visible spectrum, and black is the absence of "color."
6. A combination of red, green and blue light show as white light.
   A: True.
   Note: This question will be deleted since it goes beyond the scope of the materials covered in the context of this unit.
7. Light travels only in a straight line.
   A: False. Light can be bent by gravity and refraction.
8. A prism changes white light into colored light.
   A: False: A prism only separates the light into its component wavelengths.
9. A round glass full of water can bend light.
   A: True. The glass of water refracts the light.
10. A rainbow is a physical object (you could touch it).
    A: False. Only in Ireland...
11. Only objects that are alive radiate heat.
    A: False: Non-organic objects can also absorb heat and re-radiate it.
12. The energy of waves can be turned into other kinds of energy.
    A: True. Example: EM energy from the sun is transformed into stored chemical energy in plants.
13. The observed wavelength of a wave (including the color) depends on the relative source of the waves (an object).
    A: True. Wavelengths from stars depend on the chemical makeup of the star.
14. The observed wavelength (color) of an object depends on the relative motion of the source of light.
    A: True. Stars moving away from the earth expand their relative wavelength, and stars moving towards the earth compress their relative wavelengths.
15. The reason we "see" objects (like a shoe or a tomato) is because most of them produce and give off light.
    A: False. Some objects do give off their own light, but the reason we see objects like a shoe or tomato is because they reflect certain wavelengths of light and absorb others.
16. Colors that are perceived by the human eye are only different wavelengths of light.
    A: yes.
17. The length of a wave is related to its amount of energy.
    A: True. The higher the frequency, the more energy.
18. An object with a shiny surface does not absorb much radiation.
    A: True. These objects reflect most of the radiation.

APPENDIX B

Rubric and Task Expectations: "Tools in Space" **MBHS Common Science Assessment #3**				
G1 Describe how scientists gather data about the universe	Student provides ONE of the following about the tool: A: What is the tool and when was it used? B. What does the tool do? C. How does the tool work? D. What does the tool contribute to astronomy?	Student provides TWO of the following about the tool: A: What is the tool and when was it used? B. What does the tool do? C. How does the tool work? D. What does the tool contribute to astronomy?	Student provides THREE of the following about the tool: A: What is the tool and when was it used? B. What does the tool do? C. How does the tool work? D. What does the tool contribute to astronomy?	Student provides ALL of the following about the tool: A: What is the tool and when was it used? B. What does the tool do? C. How does the tool work? D. What does the tool contribute to astronomy?
L7 Uses computers to organize data, generate models, and do research for problem solving. Source of Evidence: Website URL	Student uses a computer during class time to research the tool but does not document sources of information.	Student uses a computer: A. to research the tool AND B. lists one complete and accurate URL (website) OR C. lists 2 URL's (websites) but is missing titles or sponsors for one or both.	Student uses a computer A: to research an astronomical tool AND B. lists 2 complete URL's (websites) with corresponding titles or sponsors.	Student uses a computer A: to research an astronomical tool AND B. lists 2 complete URL's (websites) with corresponding titles or sponsors. AND C. justifies each site as a reliable resource by providing specific, in-depth justification.

Content Requirements	**Format Requirements**
Identify what the tool is, and when it was used for astronomy research	Use complete sentences and punctuation.
Explain how the tool works.	Include Name
Explain what information it has contributed to the study of astronomy	Information must be in YOUR words.
Must have at least one clear photograph of the tool.	Information must be legible, preferably typed
Must have a bibliography listing the sources of information, which must have a minimum of two internet sources.	Ms. Millette's added requirement: Present your tool information to the class

Elementary Algebraic Models in Our World: Developing an Effective General Education Mathematics Course

Jennifer Tyne
Lecturer
Department of Mathematics & Statistics
University of Maine
tyne@math.umaine.edu

Robert Franzosa
Professor, Mathematics
Department of Mathematics & Statistics
University of Maine
franzosa@math.umaine.edu

Elementary Algebraic Models in Our World (MAT103) is a general education course at the University of Maine that was developed as an alternative to College Algebra. An important goal in the development of MAT 103 was the improvement of the students' attitudes about and understanding of simple algebraic models. MAT 103 was developed in conjunction with a new Masters in Science Teaching (MST) degree program at the University of Maine to provide a research laboratory for MST graduate students. In this paper the authors present an overview of the MAT 103 course development project, including a discussion of the background motivation, the course teaching framework, the course content framework, the course materials, and the initial evaluation of the course based on student surveys and evaluations. Appendices are included presenting a sample of class materials and a summary of the survey data.

Introduction

An ice-cold glass of lemonade on a hot summer day. To most, such a statement evokes positive feelings, memories of summers past.

Tv*x234 bew&#3 VeEd.nm#ef. To most, these letters, numbers, and symbols are a meaningless combination and evoke no feelings at all.

b = 2.97h + 29. To many students entering Elementary Algebraic Models in Our World, a general education mathematics course at the University of Maine, this is another meaningless combination of letters, numbers, and symbols. For many others, it brings up unpleasant memories of past algebra experiences. Most do not understand the linear relationship between h and b that the equation communicates.

We developed Elementary Algebraic Models in Our World (MAT103) with these feelings in mind, and with a goal of improving students' attitudes about and understanding of simple algebraic models. While we do not expect MAT103 to magically instill the same positive feelings that the lemonade evokes, we developed the course to provide an opportunity for a successful mathematics experience, something many MAT103 students have never had. And along with a successful mathematics experience, we want students to be able to recognize, interpret, and understand simple algebraic models like $b=2.97h+29$ that they might encounter outside the mathematics classroom.

Background

At the University of Maine, students must take two mathematics courses to satisfy their requirement for general education in mathematics. For many years college algebra, a course intended to prepare students to continue on to other mathematics courses, was one of the few options for students seeking to satisfy their general education requirement. The college algebra course therefore had a split audience: those taking it for their general education requirement and those taking it as prerequisite for other mathematics courses. Since college algebra is similar to the algebra sequence that most students took in high school, it provided many of the general education students with either an easy grade or another miserable mathematics experience.

Because of the number of general education students for whom college algebra was not a fulfilling experience, we realized the need to create a

Because of the number of general education students for whom college algebra was not a fulfilling experience, we realized the need to create a separate and different general education algebra course.

separate and different general education algebra course. With support from the Center for Science and Mathematics Education Research (CSMER) at the University of Maine (UM) and the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC), we developed MAT103 as an alternative to college algebra. The project objectives were twofold:

- Create a course for general education in mathematics, focusing on real life applications, enabling the students to learn to develop and interpret simple algebraic models, and providing the students with a positive mathematics experience.
- Create a laboratory for mathematics education research, where graduate students in the newly created Masters in Science Teaching (MST) program teach the course and carry out masters' degree thesis research on how students learn algebra concepts.

The course development has been a collaborative effort, with participation from UM faculty members in the Department of Mathematics and Statistics, the College of Education and Human Development, and the Onward Program (the program responsible for developmental mathematics education on campus).

MMSTEC's Attributes of an Effective Classroom document provided us with valuable guidelines in developing MAT103. In particular, presented below are five of the attributes (in bold) and a brief description of how we incorporated them into the course:

All students are engaged in learning. The algebra concepts and tools that are addressed in the course are motivated through real-world models. The students practice the full spectrum of the modeling process: modeling, analyzing, reflecting, and communicating.

Classes are communities of learners. The class is taught in a collaborative learning format. Classroom time is primarily spent with the students working in groups on an investigation related to the mathematics topic or applied model under consideration. Instructors and teaching assistants (when employed) help guide the students on the investigation when approached by a group needing assistance.

The management and monitoring of student learning is frequent and purposeful. Each group of students hands in a classroom exploration at the end of the class period. The instructor gives written feedback on the exploration and returns it at the start of the next class period. The feedback is geared toward helping guide the students' thinking about the work they do, as opposed to just providing right-or-wrong corrections.

The class focuses on fundamental concepts in the content area and the interrelationship among these concepts. The important algebraic concepts behind modeling with linear, exponential, and quadratic relationships are developed throughout the course. The students learn the associated computations and how to interpret the results of the computations in the modeling context.

Pedagogic procedures specific to mathematics and science are emphasized. The focus of the course is on developing, employing, interpreting, and communicating with algebraic models of real-world relationships. We address different approaches for deriving such models, including directly translating relationships, using inherent mathematical principles, and fitting models to data.

Teaching Framework

The MAT103 classroom is a collaborative learning environment where students learn to read, write, listen to, and speak mathematics. We have MAT103 students write about and discuss mathematics as much as possible. The discussion of mathematics takes place in class in working groups of students, and the writing of mathematics takes place primarily through individual homework projects.

The MAT103 classes are typically 40 students. The learning that takes place in the classroom is mostly active. We provide very little lecture. Almost all classroom learning takes place in small groups of students, a situation that enables students to discuss mathematics with their peers. Through this experience the students become more comfortable and confident with the vocabulary of mathematics.

We stress the importance of writing about mathematics since we want the students to develop the skills associated with the proper communication of mathematical ideas. Since many of the students are accustomed to only providing the "correct answer" in a mathematics class, the emphasis on writing is a component of the course that many find challenging.

We put the "do something with it" component of the traditional algebra course into a larger context of deriving, interpreting, and reflecting.

Content Framework

In a traditional college algebra course, students encounter problems where they are given information and are asked to do something with it, as in the following:

> The humerus is the bone that runs from your shoulder to your elbow. It has been determined that for males the relationship between humerus length h and total body height b (both measured in inches) is $b=2.97h+29$. A male who is 74 inches tall will have a humerus that is how long? How tall is a male who has a humerus that is 16 inches?

Although this kind of problem is often used to introduce students to mathematical problem solving, it leaves many unanswered questions. Who determined this equation? How did they determine it? What does it tell us? How closely does it reflect the actual relationship?

In such a situation students become accustomed to accepting equations as given, without understanding where they come from, whether they are appropriate, or how to interpret them. In MAT103 students learn how to determine the equations, interpret the equations, communicate with the equations, and use the equations in applications. We put the "do something with it" component of the traditional algebra course into a larger context of deriving, interpreting, and reflecting.

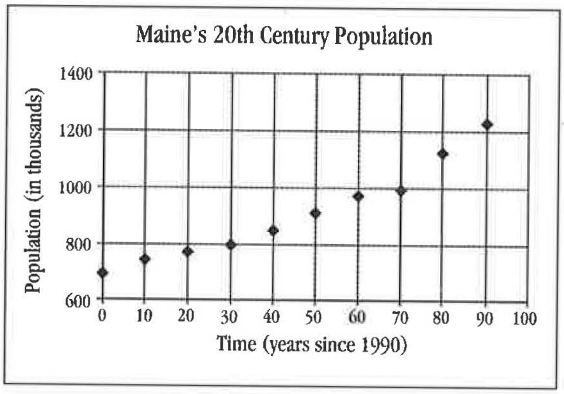
To illustrate the learning process, we will use 20th century population data for the state of Maine, summarized in Table 1.

TABLE 1.
MAINE'S 20TH CENTURY POPULATION, IN THOUSANDS (U.S. CENSUS BUREAU).

Year	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990
Pop	694	742	768	797	847	913	969	992	1125	1228

MAT103 students learn to communicate information graphically. An emphasis is put on creating effective graphs, with appropriate scales and meaningful labels and titles.

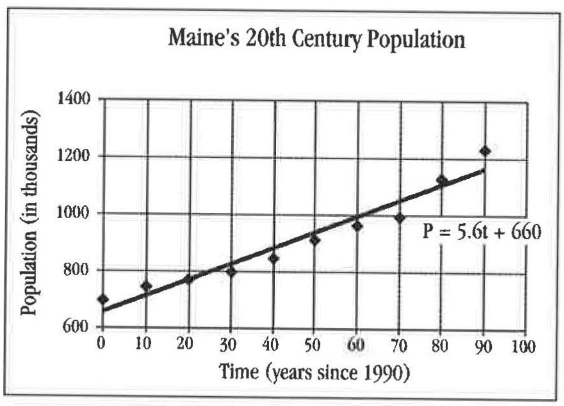
FIGURE 1.
GRAPHICAL REPRESENTATION OF DATA.



Along with applying derived models, the students reflect on the model's validity by addressing questions such as, "Is the prediction reasonable?" and "What assumptions should be changed in order to improve the model?"

MAT103 students learn to derive models. Throughout the course, we focus on the model-building process, emphasizing derivations of algebraic relationships.

FIGURE 2.
GRAPH OF DATA AND LINEAR MATHEMATICAL MODEL.



To derive a model by approximating a data set, as in the case of the Maine population data, students use sliders, a software tool that allows the user to change parameter values and view the graph simultaneously, in order to find the most appropriate "by-eye" model. This allows students to gain an understanding of what it means to be a best-fit model and an understanding of the role that different parameters play in the general forms of the algebraic equations they use. We then introduce the least-squares statistical method and have students use the computer to find the least-squares model.

MAT103 students learn to interpret models. From the Maine population model, $P = 5.6t + 660$, students are able to interpret the parameters, understanding that the model approximates the 1900 population at 660,000 and the average growth rate from 1900 through 1990 at 5600 people per year.

MAT103 students learn to apply models. Students answer questions like, "What will the population of Maine be in the year 2010?" by applying the model and predicting that in the year 2010, the population of Maine will be $P = 5.6(110) + 660$ or 1276 thousand people.

MAT103 students learn to reflect on models. Along with applying derived models, the students reflect on the model's validity by addressing questions such as, "Is the prediction reasonable?" and "What assumptions should be changed in order to improve the model?"

While traditional college algebra courses focus on achieving mastery in the skills needed to succeed in pre-calculus, MAT103 focuses on having students learn mathematics through modeling real-world phenomena and relationships. We spend the first few weeks of the course working on developing the students' understanding of equations and graphs, and then spend the rest of the semester on modeling, specifically focusing on linear, exponential, and quadratic models.

Course Materials

We do not use a textbook in MAT103; instead we provide materials (described below) that have been created collaboratively by the team of faculty involved in developing the course. The course materials are a work in progress, continually being refined and improved each semester. The course materials consist of:

Classroom Explorations: These are the group assignments that are addressed each class period. The explorations allow students the opportunity to explore the mathematics topics currently under investigation in the course. See Appendix A for a sample classroom exploration on examining change, an exploration that students complete as we end the section on linear models and begin the section on exponential models.

Class Notes: Class notes provide a summary of the concepts and tools that the students explore in class.

Tech Notes: Technology notes are provided to assist students in using the software that we use in the course.

Practice Exercises: These are optional exercises that provide students with an opportunity to practice the tools used in explorations and homework projects as well as an opportunity to work on routine problems such as solving equations and graphing equations.

Quizzes: Four graded quizzes are given during the semester and one cumulative final quiz is given during the final exam period. The quizzes assess student knowledge of concepts and the students' ability to properly use the tools developed in explorations and homework projects.

Homework Projects: The homework projects are investigations into an applied problem that require the students to use the tools developed in the course. They are an important component of the course through which the students learn to apply the tools from class, to write about mathematics, and to use technology. Each student hands in an individual project write-up, but the students are permitted and encouraged to work together on the investigation in the homework project. See Appendix B for a sample homework project on exponential decay models.

"This class took a hands-on approach to mathematics and allowed us to apply mathematical concepts learned in the classroom to real-life everyday situations. I was pleasantly surprised by this class."

Course Evaluation

Course evaluation to date has consisted of qualitative feedback from students on end-of-semester course evaluations and results from attitude surveys (described further below) administered at the beginning and the end of the semester.

For most students, MAT103 is a different kind of mathematics experience, and for many it is a welcome change from the traditional mathematics classroom. This is evident from the many positive responses we have received from the students on their course evaluations. Most students appreciate the applied nature of the course, as described by one student on the end-of-semester evaluation: "This class took a hands-on approach to mathematics and allowed us to apply mathematical concepts learned in the classroom to real-life everyday situations. I was pleasantly surprised by this class." These comments are typical of those that we have received on the evaluations.

While many students are apprehensive at first about working in groups, most come to enjoy the experience and eventually see the benefits of group learning. The biggest hurdle that we have seen is for students to learn how to write about mathematics. To most, a mathematics assignment that requires writing is an unfamiliar and unwelcome undertaking. As one student said, "Math and words shouldn't go on the same page." It often takes two or three homework projects before the students understand what is expected of them. Many come into the class believing that as long as they get the algebra correct, they should not be penalized for poor presentation.

While some of the students who previously struggled through algebra also struggle in MAT103, many let us know that they finally see the big picture and appreciate learning mathematics in the context of applications. Based on student feedback and our intuition and experience, we believe that we have been successful in providing a positive mathematics experience for many of our students.

We further wish to know if the students' attitudes and beliefs about mathematics are changing as a result of their experience in MAT103. In order to address this and measure change in students' attitudes, beliefs, and assumptions about mathematics, we administered a survey, both during the first day and the last week of the Spring 2004 semester. The survey, called the Mathematics Disposition Survey (MDS), was developed by John Donovan, a mathematics education faculty member at the University of Maine, and by Richard Beveridge, a graduate student working with John. The 31-statement Likert-scale survey (strongly agree - strongly disagree) was adapted from the Maryland Physics Expectations (MPEX) survey. The MPEX survey was developed at the University of Maryland and has been used in first semester physics courses at universities and colleges around the country (Redish, Saul, Steinberg, 1996). A copy of the MDS and a summary of the survey results from Spring 2004 is presented in Appendix C.

Examining our MDS results from Spring 2004, fourteen survey statements showed a significant change in student response from the beginning of the semester to the end. For the following eight statements, the students disagreed more at the end of the semester:

- Statement 4: I often read a mathematics textbook in detail and work through many of the examples given there.
- Statement 10: Learning mathematics requires that I substantially rethink, restructure, and reorganize the information that I am given in a class and/or in the text.
- Statement 12: Learning mathematics is nothing more than acquiring knowledge that is specifically located in the equations, definitions, and theorems given in class and/or in the textbook.
- Statement 13: In doing a math problem, if my calculation gives a result that differs significantly from what I expect, I'd have to trust the calculation.
- Statement 14: The derivations or proofs encountered in a mathematics course or text have little to do with solving problems or with the skills that are needed to succeed in a course.
- Statement 15: Only very few specially qualified people are capable of really understanding mathematics.
- Statement 18: If I don't remember a particular equation needed for a problem in an exam there's nothing much I can do (legally!) to come up with it.

For the following six statements, the students agreed more at the end of the semester:

- Statement 7: I see a relationship between what I learn in mathematics and what I experience in the real world.
- Statement 8: A good understanding of mathematics is necessary for most students to be able to achieve their career goals. Simply getting good grades is not enough.
- Statement 16: To understand mathematics, I sometimes think about situations in my everyday life and relate them to the topic being analyzed.
- Statement 24: Learning mathematics helps me understand situations in my everyday life.
- Statement 25: When I solve most mathematics problems, I explicitly think about the concepts that underlie the problem.
- Statement 30: I use the mistakes I make in solving mathematics problems as clues to what I need to do to understand the material better.

The changes in response to these fourteen statements are almost all welcome changes. The exceptions are in statements 4 and 10, both which refer to textbooks. Since we do not use a textbook in the course, these unwelcome results are not surprising.

We are encouraged by the results that we have seen with the MDS, especially in light of the results from the MPEX. In introductory physics courses, researchers have witnessed "a tendency for student expectations to deteriorate rather than improve as a result of a semester of introductory physics" (Redish, Saul, Steinberg, 1996).

Therefore, we believe that the survey results reinforce the positive qualitative feedback we have received from students.

Conclusions and Next Steps

We have completed our first project objective: to create a modeling-oriented general education algebra course that provides a positive mathematics experience for students. We started in Spring 2002 with two sections of the course, and each semester since then we have run three to five sections of the course with approximately forty students per section.

We are now beginning to focus on our second objective: creating a laboratory for mathematics education research. With the start of the new Masters in Science Teaching (MST) degree in the College of Liberal Arts and Sciences, graduate teaching assistants are taking part in teaching and research in the MAT103 classroom. And while MAT103 is not required for education majors, many of them take the course. We welcome the opportunity to share this different approach to teaching mathematics with our future teachers. Lastly, we hope that our innovative approach to teaching algebra might encourage students to consider a career in teaching.

The successes we have seen thus far in MAT103 can best be summarized by our students, one of whom stated on the end of semester course evaluation, "MAT103 taught me more about thinking about math that I'd ever imagined. I was thrilled to find a completely new way to really learn and digest mathematical concepts.... I definitely want to incorporate some of this style into my own classroom someday."

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Robert Franzosa is a Professor of Mathematics at the University of Maine and is one of the co-principal investigators for the Maine Mathematics and Science Teaching Excellence Collaborative grant. He has been on the faculty of the University of Maine since 1983. His work for the Department of Mathematics and Statistics has included research in the areas of dynamical systems and applied topology, applied mathematical consulting, teaching a wide variety of courses, curriculum development, and education outreach.

Jennifer Tyne is a lecturer in Department of Mathematics and Statistics at the University of Maine. She has an MS in operations research from the University of North Carolina. Her interests include mathematics education and curriculum development.

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"MAT103 taught me more about thinking about math that I'd ever imagined. I was thrilled to find a completely new way to really learn and digest mathematical concepts.... I definitely want to incorporate some of this style into my own classroom someday."

APPENDIX A

Classroom Exploration Example—Examining Change

1. Consider the data in the table below:

X	0	5	10	15	20	25	30	35
Y	27	35	43	51	59	67	75	83

A. This data set is exactly linear. What do you think is meant by that?

B. Plot the data set on the graph below:

C. What do you observe in the pattern of the plotted data? Was this expected? Why or why not?

D. Derive a linear equation that fits the data set.

E. Does every point in the data set satisfy the equation derived in D? Was this expected? Why or why not?

F. In part A, you observed that every time X changed by 5, Y changed in a certain way. What part of the equation that you derived in part D explains this observation?

2. Consider the data in the table below:

X	0	1	2	3	4
Y	4	12	36	108	324

A. What do you notice about how Y changes every time X changes by 1?

B. Do you think that this data set is exactly linear? Why or why not?

C. In part A, you observed that every time X changed by 1, Y changed in a certain way. The change in Y does not occur by adding the same amount to Y (as it does in the data set in #1), but it occurs how?

D. Plot the data set on the graph below:

E. The data set is said to be exactly exponential. An exponential equation is in the form $Y = b(r^X)$. Try to find an exponential equation that fits the data set. [Do not worry if you do not know how to do this. We will learn how in upcoming explorations.]

3. Of the following data sets, one is exactly linear, one is approximately linear, one is exactly exponential, and one is approximately exponential. Even though we have not yet explained what these expressions mean, try to determine which data set below is of which type. In each case explain your reasoning based on your understanding of what you think these expressions mean.

X	0	1	2	3	4
Y	47	70	94	115	138

X	0	1	2	3	4
Y	6	12	24	48	96

X	0	3	6	9	12
Y	3	9	25	73	222

X	0	4	8	12	16
Y	12	21	30	39	48

APPENDIX B

Homework Project Example

The Bald Eagle Murder Mystery

You are a park ranger and wildlife biologist at Big Cypress National Preserve in Florida. Your focus is bringing the bald eagle population back after years of decline. On your daily afternoon rounds of the park, you discover (at 3:00 p.m.) a dead bald eagle that has been impaled by an arrow. You are determined to find the eagle killer so you begin an investigation. Present your findings as a report to the District Law Enforcement Ranger.

You took the body temperature of the eagle at the time you found it and then again three hours later. The body temperature readings are 88.8°F and 81.5°F, respectively.

Meanwhile, you start investigating who could have committed the crime. You find two archers in the region. The first archer (Billy) has an alibi from 11:00 a.m. to 1:00 p.m., when he was having lunch at the local diner. The second archer (Wally) has an alibi between 9:00 a.m. and 11:00 a.m., when he was at his campsite with his friends eating breakfast. Your knowledge of algebra will allow you to create an exponential decay model to find the time of death and implicate one of the two suspects in the killing.

You know that in order to calculate an accurate exponential decay model of the eagle's body temperature, you have to know the limiting value (the temperature of the park). You don't know the exact temperature during the day, but you know that it was between 45°F and 62°F.

- You will examine two possible exponential decay models with limiting values ($B = ar^t + L$), where B is the body temperature of the bald eagle and t is the number of hours since you found the body (3:00 pm). For the first model assume that the park temperature is 45°F, and for the second model assume that the park temperature is 62°F. For both models you need to assume that the park's temperature is constant throughout the entire day of interest. To create the models, use the two temperature readings above and the limiting value. In your write-up describe clearly how you arrive at your two equations. Carry your r-value out to three decimal places.

- Use Fathom to plot the two equations, showing a time period (on the x-axis) from 6 hours prior to finding the eagle to 3 hours after finding the eagle.

- When alive, the Eagle's body temperature is 105°F. You can estimate the time of death of the eagle, by determining how far prior to 3:00 the temperature of the body was 105°F. For each

equation, determine the time (t) when the temperature was 105°F. Show your algebraic steps.

- Confirm your results by showing on the graph the points that represent the time of the killing (i.e., the time when the temperature was 105°F).

- If the park temperature was 45°F, who was responsible for the killing and how can you tell? If the park temperature was 62°F, who was responsible for the killings and how can you tell? Is the same conclusion reached both temperatures?

Make sure your report is convincing so that, if possible, the District Law Enforcement Ranger can make an arrest.

APPENDIX C

Mathematics Disposition Study

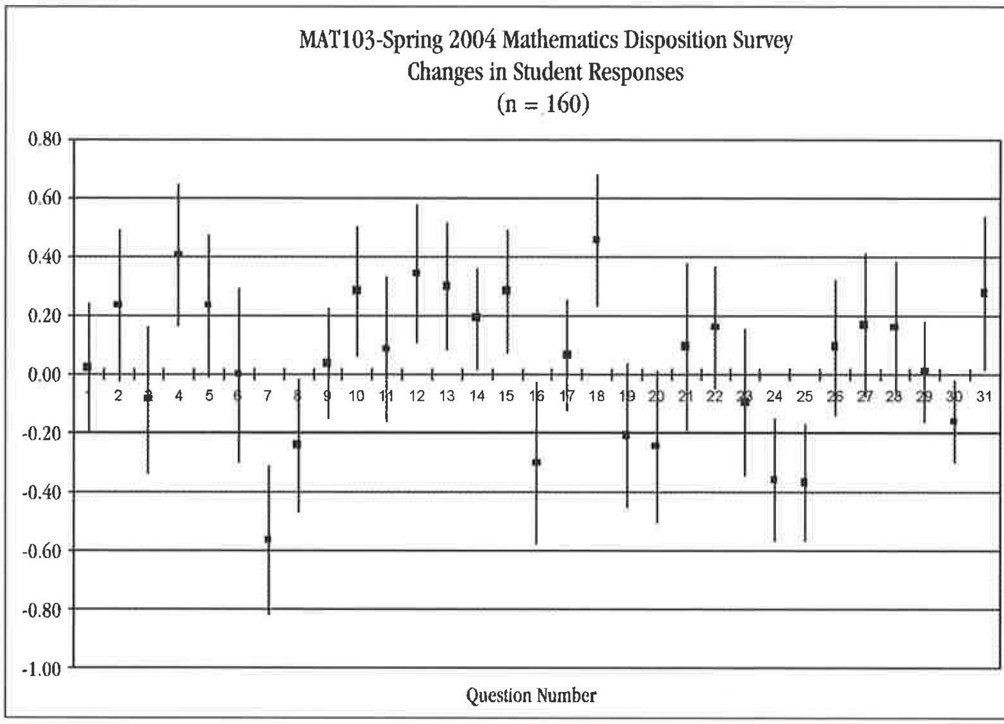
Donovan and Beveridge, 2004

The Mathematics Disposition Survey that we administered in Spring 2004 consists of the thirty-one statements presented below. Students are asked to respond to these statements by selecting a number from 1 to 5, where 1 represents "strongly agree", 2 represents "agree", 3 represents "neutral", 4 represents "disagree", and 5 represents "strongly disagree".

1. All I learn from a derivation or proof of a formula is that the formula obtained is valid and that it is OK to use it in problems.
2. Problem solving in mathematics basically means matching problems with facts or equations and then substituting values to get a number.
3. I spend a lot of time figuring out and understanding at least some of the derivations or proofs given either in a lecture or in a text.
4. I often read a mathematics textbook in detail and work through many of the examples given there.
5. Typically, I do not understand mathematical equations and definitions in an intuitive sense; they just have to be taken as givens.
6. The best way for me to learn mathematics is by solving many problems rather than by carefully analyzing a few in detail and trying to understand the underlying concepts.
7. I see a relationship between what I learn in mathematics and what I experience in the real world.
8. A good understanding of mathematics is necessary for most students to be able to achieve their career goals. Simply getting good grades is not enough.
9. Knowledge in mathematics consists of many pieces of information each of which applies primarily to a specific situation.
10. Learning mathematics requires that I substantially rethink, restructure, and reorganize the information that I am given in a class and/or in the text.
11. Understanding mathematics is primarily achieved by memorizing facts and procedures. Insight or creativity has little to do with it.
12. Learning mathematics is nothing more than acquiring knowledge that is specifically located in the equations, definitions, and theorems given in class and/or in the textbook.
13. In doing a math problem, if my calculation gives a result that differs significantly from what I expect, I'd have to trust the calculation.
14. The derivations or proofs encountered in a mathematics course or text have little to do with solving problems or with the skills that are needed to succeed in a course.
15. Only very few specially qualified people are capable of really understanding mathematics.
16. To understand mathematics, I sometimes think about situations in my everyday life and relate them to the topic being analyzed.
17. The most crucial thing in solving a math problem is finding the right equation to use.
18. If I don't remember a particular equation needed for a problem in an exam there's nothing much I can do (legally!) to come up with it.
19. If I came up with two different approaches to a problem and they gave different answers, I would not worry about it; I would just choose the answer that seemed most reasonable. (Assume the answer is not in the back of the book.)
20. Mathematics is related to the real world and it sometimes helps to think about the connection, but it is rarely essential for succeeding in a mathematics course.
21. The results of an exam don't give any useful guidance to an improved understanding of the course material. All the learning associated with an exam is in the studying that occurs before it takes place.
22. The main purpose of studying mathematics is learning how to solve math problems.
23. It is possible to pass most mathematics courses (get a "C" or better) without understanding the underlying concepts very well.
24. Learning mathematics helps me understand situations in my everyday life.
25. When I solve most mathematics problems, I explicitly think about the concepts that underlie the problem.
26. Understanding mathematics basically means being able to recall something you've read or been shown.
27. Spending a lot of time (half an hour or more) working on a problem is a waste of time. If I don't make progress quickly, I'd be better off asking someone who knows more than I do.
28. A significant problem in mathematics courses is being able to memorize all the required information.
29. One of the main results of studying mathematics is to learn how to reason logically.
30. I use the mistakes I make in solving mathematics problems as clues to what I need to do to understand the material better.
31. To be able to use an equation in a problem (particularly in a problem that I haven't seen before), I need to know more than what each term in the equation represents.

We examined the change in the average response for each of the 31 statements on the survey. Figures 3 shows the results for Spring 2004 (106 respondents). For each of the 31 questions, the change in the mean response (end of semester minus beginning of the semester) is presented along with bars that represent two standard errors away from the mean change.

FIGURE 3.
DISPOSITION SURVEY RESULTS



Any of the standard error bars that do not touch the horizontal line corresponding to a mean change of 0 signify a significant change in student response. In Spring 2004 statements 4, 7, 8, 10, 12, 13, 14, 15, 16, 18, 24, 25, 30, and 31 had significant change.

Revitalizing an Introductory Environmental Science Course for Active Learning and Student Engagement

Robert M. Sanford
Department of Environmental Science
University of Southern Maine
rsanford@usm.maine.edu

A college introductory environmental science course is revamped to promote active learning. Several components of the improved pedagogical approach are summarized.

Introduction

A variety of factors have merged to influence my teaching, especially in my introductory environmental science classes. The greatest influences have been my five-year involvement with MMSTEC (Maine Mathematics and Science Teaching Excellence Collaborative) and my participation in SENCER (Science Education for New Civic Engagements and Responsibilities). The National Science Foundation (NSF) funded both programs. Concurrently, my own growth as a teacher-scholar led to a self-perceived need to change. MMSTEC and SENCER introduced me to "inquiry-based learning." This was not a topic that came up during the pursuit of my PhD although, of course, it was the essence of what I was doing in graduate school. Gradually I have become aware of the need for a variety of effective instructional techniques, and have learned about the benefits of field experiences and the need for accurate and useful assessments.

The SENCER project connects science and civic engagement by teaching through complex, capacious and unsolved public issues, such as natural catastrophes, water quality, HIV disease, the Human Genome Project, energy alternatives, and nuclear disarmament. In August of 2003 and 2004, I attended the SENCER Institute in Santa Clara, California, to work with a team of USM professors tasked with creating a suite of Honors Program general education science courses. While at the institute I came to the startling realization that most of the more innovative science courses taught by the participants (faculty from over 40 other states and countries) were being delivered to non-science majors—usually as their only science course. I canvassed a number of professors and they all said essentially the same thing: that courses for non-majors were seen as insignificant (and the students less worthy) by their respective departments and therefore, the professors were free to be innovative. This led me to question whether or not my own environmental science course was sufficiently interesting or innovative. I wanted to see more student engagement in my class and I decided to learn more about teaching and learning.

An article presented at the SENCER Institute (Etkina and Mestre, 2004) sparked my interest in what research had been done to understand how students learn about science. The article reinforced the concept of active learning—a topic that played key roles in SENCER and MMSTEC discussions. Having come to question the nature of passivity in my classroom, I wondered if I, too, was passive in my teaching and if my students were passive in their learning. Determined to put more vigor into my teaching, I also sought ways to stir things up and awaken the passion that I supposed must be there in my students.

While the reform of my teaching has helped me redefine myself and change all of my courses as well as the writing, research, and service I do, perhaps the best example of my progress can be seen in the evolution of one particular course at USM, ESP 101 Fundamentals of Environmental Science. The lecture and laboratory course serve as general science electives for students, provide a foundation for environmental science majors, and count as science courses for pre-service teachers. I teach either the

lecture or laboratory portion (ESP 102) at least once a year; the course has come to symbolize my commitment to student learning and to my profession. As a recruitment tool for attracting potential environmental science majors, the course demands my best efforts. Further, I am committed to the philosophy that if a student only takes one "general education" science course, it ought to be an interdisciplinary one such as environmental science—a perspective shared by the other faculty in my department. My colleagues and I think carefully about the need to be good practitioners and role models for prospective teachers; we don't want to be seen as "do-what-we-say-not-what-we-do" teachers.

My colleagues and I think carefully about the need to be good practitioners and role models for prospective teachers; we don't want to be seen as "do-what-we-say-not-what-we-do" teachers.

Naturally, if environmental science is important—and it is—and if I care about my job—and I do—I want to do whatever I can to teach better. Active learning and inquiry-based learning call for setting up learning scenarios, and trying to remove the "noise" and other barriers that interfere with student discovery. The first step in my redefinition was to immerse myself in available support networks. As I worked on my ideas of teaching, and my own sense of self as a person who facilitates learning, I took advantage of MMSTEC seminars, institutes, and resources. MMSTEC sent an observer to my classroom to help me understand my teaching style. I was ready to make whatever changes necessary to improve student learning. The observations helped me to think about the nature of my interactions with students and their interactions with each other.

Course Changes

I made changes to my course structure, my teaching style, the support services I offer for the course, and my methods for evaluation of student achievement. Each change is intended to target at least one aspect of the course: student engagement and interest level, a sense of classroom community, and promoting critical thinking and depth of understanding rather than rote knowledge. Throughout, my goal is to spark student interest in environmental science, expand student science literacy, and increase student learning. To do this, I try to dissolve obstacles and create opportunities beginning with the first day of class.

Course delivery starts with communicating clear expectations via the syllabus—a form of social contract. My syllabus is at least seven pages and is fairly comprehensive, covering what the course offers in content and structure, my expectations of students, a list of available course and institutional support services, and performance assessment. The student can see from the syllabus that the course is geared toward active learning. The syllabus details many topics including science content, attendance and illness policies, and grading policies. For example, the following is included in my syllabus with regard to grading policies:

> A = Excellent work documented in the portfolio in an impressive manner. The student has clearly learned and obtained an excellent level of proficiency in critical thinking and application of introductory environmental science principles. Aggregate 90 to 100% performance on exams and other evaluative instruments—even if the student has not actually earned quiz grades of 90% or above, it is clear from the documentation in the portfolio that the student has learned from the quizzes and has an A level of competence as a result. Presents quality writing, research, and analytical skills, and has superior documentation. Extra work has been done, showing the student has thought about and learned from the material. No significant errors or flaws. The student has a laudable grasp of fundamental environmental science concepts and issues.

A syllabus, as a support for learning rather than just for teaching, should guide the way to additional resources. For example, throughout the course, I emphasize the importance of good writing, since I believe good writing is integral to good thinking. In my experience, a student who can write clearly and effectively about a topic generally has a better understanding than a student who cannot, and the act of writing is itself a clarifier. Accordingly, my syllabus contains a recommendation for Diana Hacker's A Writer's Reference (2003) and her free web site: http://www.bedfordstmartins.com/hacker/writersref/. To help ensure their papers meet my expectations,

students can also submit draft assignments for my review and comments, and they can fix final assignments for their portfolios. This makes their writing much more interactive as they progress through iterations. Many of my introductory students are in their first semester and are encouraged to take advantage of the campus Writing Center. Because the syllabus is crafted to reduce mystery and uncertainty (other than the mystery and wonder of science), the student can more confidently focus on learning and engagement in the classroom.

In an effort to create a sense of community and collaboration in my classroom, I wanted to see students take a larger role in the class. Therefore, my teaching style and approach has been modified so that lectures are no more than a third of the course. In-class group assignments and presentations abound. Each class session has student-directed group or individual work, and includes student reporting on learning activities and assignments. I discuss with the students their learning styles, and I use one-minute feedback and other teacher assessments throughout the course to ensure that I am keeping pace with student needs.

I try to gear the course to what the students will retain (and need) a year from now, not just for what they need during the semester. Depth of student learning is more important than getting through all the content. There will always be new content and if they learn how to learn, and they will be in a better position to assimilate new knowledge as the need arises. To that end, many of the course tasks are inquiry-based, reflecting the rather open nature of environmental science where answers are not always clear and where collaboration is often necessary. For each chapter or topic I present a problem (or have the students select one) for which there is no easy or clear-cut answer, such as managing fossil fuel resources—a problem the students are more likely to face in the "real world." The students "brainstorm" an approach to the problem for presentation to the rest of the class. This serves the dual purpose of promoting student collaboration skills while giving them practice at thinking through a challenge by themselves.

The course now includes civic engagement assignments (see Appendix A for an example assignment guide). Students apply environmental science to a matter of particular relevance to them—another way for them to contextualize their learning, have greater involvement in it, and create a project that serves a public need. The open-ended nature of the assignment has led to a great variety of projects, including a brochure on the pollutant effects of airplane de-icing fluid, a preschool lesson plan on product packaging, and a booklet on wetlands.

I wanted the students to take more ownership of their work and to know that I would evaluate the efforts they put into their own inquiries. Accordingly, the major student product for the course is now a portfolio rather than a suite of exams. Periodically, I collect the portfolios and provide comments, helping it to be a formative assessment tool. The portfolio provides an opportunity for students to correct and include their assignments, quizzes, and other learning, including separate readings and investigations they undertake on their own as part of the course. To reduce uncertainly, the students receive a grading guide for the portfolio (see Appendix B), and I let them know I have no problem with everyone doing an excellent job. The portfolio is something the student can have back after the semester ends, as a record of their learning.

I wanted the students to take more ownership of their work and to know that I would evaluate the efforts they put into their own inquiries.

Because students can benefit from an expansion of the class environment outside the parameters of the meeting times, I use Blackboard, an online course support service subscribed to by my institution. The service helps students have informed interactions with their peers, have conversations with me outside of the classroom or office hours, and receive additional information for assignments. My lecture notes, grading guides, and assignments are posted on Blackboard, as are discussion threads for study groups, student concerns, hypertext links to external resources, and assignments. As the instructor, I can monitor the nature and degree of student visits to the course site; the results and the course evaluations indicate Blackboard is popular with students, especially for assignments and for the chapter notes. All this contributes to student engagement, participation, and accountability.

Do These Changes Promote Student Learning

Modifying this introductory science course has given me more satisfaction in teaching.

Effective student learning seems to me to be the result of a synergistic interaction and connection from a wide variety of events. Student performance and the one-minute assessments inform me about the nature and effectiveness of their learning and the things they and I do to promote it. From the very beginning of the course, the more detailed syllabus promotes clarity in the students' understanding of the course expectations, including the approach we take to learning. The system of collecting and offering feedback on writing appears to lead toward better expression of thought. By not having to listen to me lecture for more than a third of the course, the students are taking a much greater ownership of the work they do. The open-ended problems seem to do more to stimulate student thought by allowing them to choose the direction and by showing the validity of a variety of approaches to complex environmental issues. Using a variety of teaching techniques has increased the likelihood that at least one will work well for each student, as shown in the one-minute assessments, which also inform me about the nature and effectiveness of other aspects of the course.

Since I have been using the portfolios and instituted the other changes, I have noticed a moderate increase in student grades. Because I cannot directly compare the grades from differently structured course sections, I must ask myself if the increased student performances are due to my own grading biases or are a true reflection of increased student learning. The portfolio is a difficult concept for some students—I always have several who are averse to it, and it adds much more to the time I spend assessing student learning. Each portfolio includes a memorandum from the student addressing his or her learning; in many of these the student acknowledges a personal change. So, does the portfolio do a better job of stimulating learning and are the students able to keep up with their peers who have taken an environmental course that emphasized conventional tests? Slater (1997) found that students in a large environmental science class that used portfolio assessment did in fact score at least as well as their peers on traditional multiple choice exams, and reported feeling less anxious and having greater appreciation for environmental science. While I do not have the quantitative data from a formal study to speculate on would-be exam performance, based on anecdotal evidence from student feedback I do believe that these attitudinal gains did occur with my students.

The student postings and communications contained in the on-line ("Blackboard") portion of the course indicate to me that the students do tend to take a more active role in their learning and that they benefit from the changes I have made in the course. Similarly, their presentations of the civic engagement projects also show greater ownership of their learning and an increased ability to see the relevance of environmental science to their lives compared to their perspectives at the start of the course, and compared with my recollections of students from classes in the years before I took this approach.

Pretests and posttests are naturally desirable in measuring student gains. To this end, I have been experimenting with a draw-an-ecosystem test, in which I ask students at the start and end of the course to draw an ecosystem, labeling it as they see fit, and choosing what processes and concepts to display. I remind them that this is not an art course and to not worry about art talent. This assignment also helps them personalize their learning through contextualization; ecosystems become real places not just abstract concepts.

In an attempt to improve active learning, a colleague and I collected our laboratory and class assignments together into a text (Wagner and Sanford, 2005), which we now use to supplement the main text for the course. We could not find another short environmental science book that fully met our needs and our teaching orientations and therefore viewed this writing task as an ethical and professional obligation, putting our pens where our mouths were.

Modifying this introductory science course has given me more satisfaction in teaching. The students seem to learn better from these changes and I am having fun teaching it. However, there is still much to do. I want to see how many of our students go on to become science majors, how many take more science courses, how many find an increased appreciation of science, and how many feel the course helped them later in life. And I want to see how much better I can make this course and my other courses. But I am just starting out with this inquiry and shall have to be patient.

Robert Sanford is Associate Professor of Environmental Science and Policy in the Department of Environmental Science at the University of Southern Maine. An environmental planner by training, Rob made a mid-career switch to teaching and remains fascinated with the learning process. He has co-authored a number of books and articles pertaining to environmental education

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APPENDIX A

ESP 101 Independent service-oriented project grading guide.

Name________________________________ Title of project________________________________

Here is what I look for in grading the project. The more you can explain how the project meets these criteria the easier it will be to evaluate it. Include this sheet when you submit your project.

__ Documentation includes a clear description of the project, what the student intended to accomplish, how the project accomplishes the objectives, and the student's assessment of the project's strengths and weaknesses.

__ Class presentation on project.

__ Project incorporates learning from this course.

__ Project has a civic benefit—it meets a public need encountered by the student.

__ Project reflects a reasonable amount of work (equivalent to at least 10% of a 3-credit course). Project is quality work—clearly not slapped together at the last minute,

__ Project shows creativity and initiative.

__ Student has consulted appropriate authority in crafting the project.

__ Viability of project. (Either it has been completed and submitted for public use already or there is a clear likelihood and plan for this to occur after the semester ends.)

__ Project shows college-level work. For example, if it is a written project it has been edited and reflects good writing principles. If it is a workshop or video or other performed activity it too reflects good communication skills and attention to detail.

__ Supporting material, including comment letters, as appropriate from people in a position to evaluate the project.

APPENDIX B
ESP 101 Portfolio grading guide

Name____

The portfolio assessment is a means of documenting learning outside of the normal testing process. Your portfolio is a record of the work you have done as well as your reaction to the materials and your explorations in environmental science. An orderly, well-structured portfolio represents orderly thoughts and processes. But do not let this get in the way of creativity or personal learning style. Include this sheet in the front of your portfolio. Here are the items I will use in assigning a grade:

+ o - Cover memo. Formal cover memo to me describing contents and how they document the learning the student has achieved in this course. Include how the degree of knowledge/expertise obtained fits into my grading categories in the syllabus (student explains what grade they have earned and why). In this memo, student has analyzed their academic strengths and areas to work on in the context of the course subject matter. Cover memo addresses record of attendance: presence/absence in class as well as participation.

+ o - Table of contents. Portfolio has a table of contents dividing up contents by week. Table lists items I have handed out in class as well as things selected by/done by the student. Table of contents matches what is actually in the portfolio.

+ o - Portfolio is neat and organized efficiently in a three-ring binder—I can easily find my way around in it.

+ o - Student has reacted to the assignments, including corrected homework and tests as well as thoughts and comments on various tasks, activities, and assignments.

+ o - Portfolio is complete; not missing a significant number of assignments—if student has missed a class she or he has obtained a copy of the materials and completed any worksheets on his or her own.

+ o - It is clear student has read and thought about the materials, as demonstrated by what is in the portfolio.

+ o - Student has included some extra things to document learning outside of class—things such as the critical thinking questions I've posted at the end of some of the lecture notes, or articles gleaned and reacted to from outside of class—stuff like that.

Journeys of Organization-Level Change

The Maine Mathematics and Science Teaching Excellence Collaborative's Attributes of an Effective Classroom

Francis Eberle
Executive Director
Maine Mathematics and Science Alliance
feberle@mmsa.org

The Maine Mathematics and Science Excellence Collaborative (MMSTEC) project leaders and participants developed a project vision and a public articulation of that vision called the "Attributes of the Effective Classroom (AEC)." The author describes how the project developed the AEC then used the document for evaluation, aligning the tenets of the document to the data gathered as a part of national efforts. MMSTEC hopes that the AEC's simplicity and depth can make it an enduring document in the educational landscape in Maine.

Introduction

The Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC) is a National Science Foundation (NSF) project funded for the five-year period, 2000-2005. In MMSTEC's first two years, efforts were focused on building the infrastructure to help faculty accomplish MMSTEC's goals at three different University of Maine System campuses. One goal was to improve grades 6-16 mathematics and science classrooms to focus more on student learning than faculty teaching. The identification of progress toward this goal is challenging because one has to gather information about the predominance of teaching approaches and learning in MMSTEC classrooms.

During the project's first year, MMSTEC participants discussed questions of educational philosophy, such as what is the goal of teaching, in an attempt to identify the types of data necessary to evaluate progress toward the stated goals. At an early meeting of the MMSTEC National Visiting Committee (NVC), an NVC member asked, "What will the MMSTEC classroom look like if you are successful?" This prompt forced a response to the earlier question regarding educational philosophy. The answer to this seemly simple question would, to a large extent, determine the success of the five-year project.

The literature on teaching and learning is one source of answers to the question about effective classroom practice. There are many articles, reports and documents about teaching and learning including effective K-12 and undergraduate teaching and learning in mathematics and science. While it may be informative to cite all the research over the last 20 years that forms the basis for the recommended practices at the K-16 level, for brevity I include here a summary of pertinent research documents.

In mathematics the research documents include publications from the Mathematical Association of America [MAA] (1998), Mathematical Sciences Education Board [MSEB] (1990, 1991, 1995), National Research Council [NRC] (1991) and the National Association of Teachers in Mathematics [NCTM] (1989, 1991, 1995). In science, defining documents include those of the American Association for the Advancement of Science [AAAS] (1989, 1996), and the National Research Council [NRC] (1996, 1997, 2000, 2001). Within these documents, standards for teaching mathematics and science articulate what is known about teaching and learning mathematics and science. Additionally, the National Science Foundation advisory committee (1996) and the National Research Council's Committee on Science and Mathematics Teacher Preparation determined that fundamental changes are needed for both the preparation and professional development of teachers (2001). Bransford, Brown and Cocking (1999) published a book about the cognitive processes of learning mathematics and science that directly connected how the mind stores, processes and utilizes knowledge. Some of the factors

"What will the MMSTEC classroom look like if you are successful?" ... The answer to this seemly simple question would, to a large extent, determine the success of the five-year project.

of quality teaching for learning include the following: having knowledge of possible student conceptions of ideas, helping students construct and make connections among ideas, providing a rich variety of experiences for students for effective learning to occur, being aware of what students think, and providing experiences that help students make connections among ideas. Quality teaching requires teachers to have both strong content background and the ability to help others learn that knowledge.

This literature lays the groundwork for thinking about teaching approaches in the different disciplines and what is called pedagogical content knowledge (PCK). Since the introduction of the idea of pedagogical content knowledge by Shulman in 1986, it has been discussed, refined and expanded by researchers from various disciplines. Some controversy has developed around the exact meaning of PCK, but the concept still provides a useful framework for identifying the specific knowledge and skills required to teach specific disciplines effectively. Shulman described PCK as "the most useful forms of [content] representation..., the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that makes it comprehensible for others" (1987, p 9). PCK has become common lexicon in educational research, such that books and chapters have been dedicated to the exploration of the teachers' pedagogy as it is related to their subject matter knowledge (Ball & McDiarmid, 1990; Brophy, 1991) and has been used as a major organizing construct in reviews of literature (Gess-Newsome & Lederman, 1999; Borko & Putnam,1995).

How do faculties in higher education institutions learn about and incorporate the recommended PCK? Education faculty in mathematics and science should have a good grounding in both the practical and theoretical bases for teaching science and or mathematics. In contrast, faculty in science, technology, engineering and mathematics (STEM) enter their profession with little, if any, formal background in how to help students understand their areas of expertise (Lederman and Niess, 1999). With this existing gap, MMSTEC had an opportunity to share knowledge on how to improve undergraduate student learning in STEM fields to faculty in Maine, to increase student interest and the numbers of students in STEM fields, and improve the preparation of new teachers of STEM. Therefore the need to define effective teaching was even more urgent.

Developing the Attributes of an Effective Classroom

Returning to the original question of what the classroom would look like if the MMSTEC initiative were successful, MMSTEC needed a project vision and a public articulation of that vision. The vision would provide an explicit operational framework and guide for secondary and tertiary level faculties to illustrate effective learning techniques. The challenge in creating such a document was to interpret the research about the disciplines and pedagogy, policy documents, meta-summaries, and calls for reform into a readable and easily understandable document for the grades 6-16 science and mathematics faculties.

We developed a document called the Attributes of an Effective Classroom, intentionally written to be simple, clear, and relevant based on research so it would be broadly read. There are five categories, with subsequent examples. Many people developed the document including the MMSTEC Principal Investigators (PIs), many faculty and the cross tier teaching teams at each of the initiatives' campuses, participants at Midyear Conferences, the MMSTEC National Visiting Committee and first Summer Academy participants. This wide level of input was purposeful so the Attributes of an Effective Classroom (AEC) would be seen and reviewed from many different perspectives to check for its relevance and usefulness. Thus the final document was better grounded in the literature and practice.

Attributes of an Effective Classroom

1. All students are engaged in learning.

Instructors create a learning environment that includes:

- Respect for diversity of ideas and people by valuing and challenging all learners. Examples of this include:
- Teachers select content, and adapt and design curricula to meet the interests, knowledge, understanding, abilities and experience of student.
- Teachers select instruction and assessment strategies that support the development of student understanding and nurture a community of learners.
- Teacher's course activities encourage student reflection on their learning.
- Connecting content to prior knowledge.
- The connections among content and real world phenomena are explored and valued.
- Setting intellectual expectations that challenge all learners.

2. Classes are communities of learners.

Both instructors and students:

- Respect each other.
- Take responsibility for their learning.
- Actively participate in class activities.
- Work collaboratively with colleagues and peers.
- Communicate their ideas to each other in a variety of ways.

Instructors:

- Act mostly as resource persons working to enhance and support student investigation.
- Effectively mediate the relationship between the subject matter and the students. Effective mediation means that there is a balance between "teacher as listener", "teacher as guide", and "teacher as provider of direct instruction."

** These five major attributes will be true for 6-16 classrooms. We realize that in some university upper-level mathematics and science courses, the thread between real-world application and theory becomes quite thin, and at times, apparently invisible.*

3. The management and monitoring of student learning is frequent and purposeful.

Students:

- Tell teachers what they think they need to learn.
- Reflect upon and assess their learning.

Instructors:

- Assess students' prior knowledge using a variety of assessment techniques.
- Identify student misconceptions and alternative frameworks of thought.
- Revise instructional methods to reflect students' prior knowledge and conceptual frameworks.
- Frequently assess students' progress toward clearly stated goals.

4. The class focuses on fundamental concepts in the content area and the interrelationship among these concepts.

Instructors:

- Have a deep understanding of fundamental concepts in her/his content areas.
- Are effective in teaching these concepts to students. Effectiveness includes:
- Being able to approach/explain a content area in several different ways.
- Knowing the effective balance between instructor/student explanation and further student exploration.

5. Pedagogic procedures specific to mathematics and science are emphasized.

Students:

- Use an inquiry-based approach to learning.
- Use elements of abstraction when appropriate.
- Use a variety of means to represent phenomena.
- Make predictions/hypotheses and explore ways of testing them (science), or make conjectures and explore ways to prove or disprove them (mathematics).
- Analyze and interpret data.

Benchmarking MMSTEC Progress

This link also provided an opportunity to use this data in a triangulation of data points—from the AEC, the Core Survey, Classroom observations, and other qualitative data sources—to attempt to measure the broader impact of MMSTEC.

With the completion of the AEC, the MMSTEC PIs worked to find ways of disseminating and using the AEC. In response, the AEC appeared in just about every set of materials distributed in the project. At the same time, the question was posed as to whether the AEC might also be linked to the project evaluation, since it represented the MMSTEC project beliefs about science and mathematics education. Alignment would allow for data on the impact of MMSTEC to also be collected within the framework of the AEC.

MMSTEC has two evaluation instruments for large-scale data collection developed by the Center for Applied Research and Educational Improvement at the University of Minnesota: the CORE Faculty Survey and the College Student Survey. The CORE surveys were developed to serve the National Science Foundation's Collaborative for the Excellence in Teaching Program (CETP) projects. Selected questions from the CORE are in Appendix 1. This CORE survey is a program-wide instrument, not necessarily aligned with the specific goals of any individual CETP project such as MMSTEC.

The PIs and MMSTEC evaluator met and developed an operational alignment process to correlate the five categories of the AEC with individual questions from the CORE surveys. This alignment process used a simple similarity of topics. There was no previous literature base from which to reference how to conduct this particular alignment that would have meaning for MMSTEC, and time and sample constraints prohibited a formal "factor analysis" procedure. We used informed judgment and common sense to choose and align survey items that would measure our progress toward the AEC ideals. This operational link allowed us to link responses by faculty and students on the CORE survey with the AEC principles as a measure of MMSTEC's impact on teaching. This link also provided an opportunity to use this data in a triangulation of data points—from the AEC, the Core Survey, Classroom observations, and other qualitative data sources—to attempt to measure the broader impact of MMSTEC.

In an examination of the first four years of results from the CORE survey, we found that the alignment of the CORE with the AEC may indeed be beneficial for documenting change based on the AEC categories. At the time of writing this paper, four years of CORE survey data is available and a complete analysis is yet to be conducted, so it is too early to draw any solid conclusions. However, there are some possible, interesting areas to look at for trends. I will use one example from the CORE survey data to illustrate how the link can be useful in identifying whether the AEC principles are being practiced in the classroom. The data set includes 4 years of data from AEC category 1: All Students Are Engaged in Learning—The connections among content and real world phenomenon are explored and valued. This category of the AEC relates to the instructional practices identified by Bransford, Brown and Cockling (1999), that is, helping students construct and make connections among ideas, and providing a rich variety of classroom experiences for effective learning to occur. This AEC category also relates to the PCK strategy of providing experiences that help students make connections among ideas.

Student's of MMSTEC faculty, surveyed using two different forms, showed that the large majority of students (89%, the mean over four years, [form A data]) find that "work on real world or practical issues" in the classroom is "somewhat" to "very" helpful. Students also report that this practice commonly did occur in the classes taught by MMSTEC faculty. 82.0% ±3.3%, the mean,—reports that it occurs "occasionally" to "regularly." Of the faculty of those students, 60% in the years 1 and 2, then increasing to 100% in year 4 reported they "work on problems related to real world or practical issues" (Table 1)

TABLE 1: COLLEGE STUDENT AND FACULTY SURVEY RESULTS: "SOMEWHAT TO VERY HELPFUL" TEACHING STRATEGIES AND THEIR FREQUENCY, ALIGNED TO THE AEC

Students, Form A (SA), Students, Form B (SB) or Faculty (F)	**AEC Category**	**CORE Item**	**Year 1** S_A: N= 491 F: N=16	**Year 2** S_A: N=445 S_B: N=111 F: N=20	**Year 3** S_A: N=1426 S_B: N=613 F: N=7	**Year 4** S_A: N=1650 S_B: N=812 F: N=14
Students, Form A (occurs & is somewhat to very helpful)	1	Work on problems related to real world or practical issues?	85.1%	91.3%	90.9%	87.8%
Students, Form B (occurs occasionally to regularly	1	Work on problems related to real world or practical issues?	N/A	79.8%	85.8%	80.5%
Faculty (occurs occasionally to regularly)	1	Work on problems related to real world or practical issues?	62.5%	57.9%	85.7%	100.0 %
Students, Form A (occurs & is somewhat to very helpful)	4	Completing assignments that included problems with complex solutions?	70.0%	74.0%	78.9%	80.4%
Students, Form B (occurs occasionally to regularly)	4	Completing assignments that included problems with complex solutions?	N/A	73.4%	76.0%	79.8%
Faculty (occurs occasionally to regularly)	4	Completing assignments that included problems with complex solutions?	75.0%	47.4%	71.4%	78.6%

The vision that all students (grades K-16) have access to quality instruction is not too much to ask. The simplicity and depth of the AEC will hopefully make it an enduring document to become a part of the educational landscape in Maine.

Another CORE survey item, "Completing problems with complex solutions" (Table 1), shows evidence of progress in AEC category 4: The Class Focuses on Fundamental Concepts in the Content Area and the Interrelationship Among Concepts—being able to approach/explain a content area in several different ways. Students report that frequency rose from approximately 73% to 80% in three years;, faculty responses seem fairly flat at approximately 75% (except for the outlier of 48%).

The purpose of this discussion is to determine if the use of practices supported by the AEC can be measured through the use of the CORE survey data, not why or how the changes may have occurred. As we have shown, the numbers from the CORE survey illustrate that changes occurred; the connections we draw to the AEC help show that that these principles are being incorporated into MMSTEC classrooms. There are many other questions that could be asked, such as why the students' responses stayed relatively constant while faculty increased, or what aspects in faculty teaching changed. These two examples, while preliminary, do suggest that it is possible to use the results of the CORE survey to help provide data about the implementation of AEC.

It is the hope of MMSTEC project leaders that these types of comparisons will be useful in the overall analysis of the impact of MMSTEC. Caution is needed here as these results will need much further analysis with the other data from MMSTEC before there can be useful conclusions. MMSTEC plans to include the results of this analysis in its final grant report.

Conclusion

Funding for the MMSTEC collaborative will end and faculty will continue their work with students. With the end of any grant-funded project the question is asked, "Will the reform efforts remain?" The AEC, a foundational document exemplifying many of the characteristics well documented in the literature for improving the learning of mathematics and science, exhibits MMSTEC's vision. We hope it will be carried on. If Maine educators continue to attend to the goals and practices of the AEC, the document may provide an ongoing guide for progress, as it is a framework for the individual and institutional improvement. It also can provide indicators for additional research on the impact of MMSTEC and perhaps other initiatives. If the mathematics and science faculties believe that as a part of their job they are responsible for teaching and student learning then they may achieve the AEC categories of high quality teaching. "Outstanding teaching requires teachers to have a deep understanding of the subject matter and its structure, as well as an equally thorough understanding of the kinds of teaching activities that help students understand the subject matter in order to be capable of asking probing questions." (Bransford, Brown, & Cockling, 1999. pg 176).

The vision that all students (grades K-16) have access to quality instruction is not too much to ask. The simplicity and depth of the AEC will hopefully make it an enduring document to become a part of the educational landscape in Maine. This is particularly important as many of the undergraduates in science and mathematics courses now are our future science and mathematics teachers who will be teaching the next generations of youth.

Dr. Francis Eberle serves as the Executive Director of the Maine Mathematics and Science Alliance, a profit organization working to improve mathematics and science education, with responsibilities including research, development, implementation and evaluation of programs. He is engaged in teacher preparation and development. He is co-author of Uncovering Student Ideas in Science *and author of several articles about science education, mathematics and science reform initiatives, and reports about technology use and the mathematics and science programs. He received a B.S. in Science Education from Boston University, a M.A. in Educational Psychology from the University of Connecticut and a Ph.D. from Lesley University.*

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APPENDIX 2

CORE - FACULTY SURVEY-PRE AND POST

Selected Questions only

3. Please rate the quality of the following.

	less than adequate	*adequate*	*more than adequate*	*exceptional*	*not applicable*
a. The ability of the students in the teacher preparation programs at your institution	O	O	O	O	O
b. The ability of the students in the science, technology, engineering, and mathematics (STEM) programs at your institution	O	O	O	O	O
c. The STEM knowledge of your students at your institution	O	O	O	O	O
d. The pedagogical knowledge of your students at your institution	O	O	O	O	O

Frequency Prior to [Date]				*Strategy*	*Frequency After [Date]*			
never	*seldom*	*occasionally*	*regularly*	*In your current science, mathematics or education courses, how often do students:*	*never*	*seldom*	*occasionally*	*regularly*
O	O	O	O	14. Work with other students where the whole group gets one grade	O	O	O	O
O	O	O	O	15. Participate in whole-class discussions during which the teacher talks less than the students	O	O	O	O
O	O	O	O	16. Use or make models, e.g., physical, conceptual or mathematical models	O	O	O	O
O	O	O	O	17. Write descriptions of their reasoning	O	O	O	O
O	O	O	O	18. Work on problems related to real world or practical issues	O	O	O	O
O	O	O	O	19. Perform investigative activities that include data collection and analysis	O	O	O	O
O	O	O	O	20. Make connections to other fields (science, technology, engineering, and mathematics (STEM) and non-STEM)	O	O	O	O
O	O	O	O	21. Design and make presentations that help them learn class concepts	O	O	O	O
O	O	O	O	22. Evaluate the extent of their own learning	O	O	O	O
				23. Complete assessments/ assignments that include:				
O	O	O	O	a. problems with complex solutions	O	O	O	O
O	O	O	O	b. portfolios	O	O	O	O
O	O	O	O	c. multiple choice/short answer items	O	O	O	O
O	O	O	O	d. full-length papers/reports	O	O	O	O
				24. Use technology, e.g., computers, calculators:				
O	O	O	O	a. to understand or explore concepts taught in class in more depth	O	O	O	O
O	O	O	O	b. as a tool in investigations to gather and analyze scientific or mathematical data	O	O	O	O
O	O	O	O	c. as a tool for assessment	O	O	O	O
O	O	O	O	d. as a tool to communicate with you or with other students	O	O	O	O

How often do the following strategies characterize your current science, mathematics or education courses?	*never*	*seldom*	*occasionally*	*regularly*
25. Students have a voice in decisions about course activities.	O	O	O	O
26. New information is based on what students already know about the topic.	O	O	O	O
27. Student assessment results are used to modify what is taught and how.	O	O	O	O

Indicate how much you disagree or agree with each of the following statements about teaching and learning mathematics and science.	*strongly disagree*	*disagree*	*agree*	*strongly agree*	*not applicable*
28. It is important for students to help establish criteria by which their work will be assessed.	O	O	O	O	O
29. In this institution, faculty members have a shared vision of effective instruction.	O	O	O	O	O
30. In this institution, faculty are well informed about the national education standards, e.g., AAAS, NRC, and NCTM, for the courses they teach.	O	O	O	O	O

Indicate how much you disagree or agree with the following statements.	*strongly*	*disagree*	*agree*	*strongly*
35. Truly understanding science in the science classroom requires special abilities that only some people possess.	O	O	O	O
36. Truly understanding mathematics in the mathematics classroom requires special abilities that only some people possess.	O	O	O	O

CORE 6-12 STUDENT SURVEY—FORM A

Selected Questions Only
The following questions are about your class.
How helpful do you think the following class activities were?
If an activity did not happen in your class, mark "Did not happen."

	did not happen	*did happen and not helpful*	*did happen and somewhat helpful*	*did happen and very helpful*
2. Working with other students where the whole group gets the same grade	O	O	O	O
3. Participating in whole-class discussions where your teacher talks less than the students	O	O	O	O
4. Using or making models, e.g., physical, conceptual or mathematical models	O	O	O	O
5. Writing about why you think something	O	O	O	O
6. Working on problems related to real world or practical issues	O	O	O	O
7. Doing activities that allow you to collect information (data) and figuring out what the information means (analysis)	O	O	O	O
8. Making connections to other science, technology, engineering, and mathematics (STEM) and non-STEM fields	O	O	O	O
9. Designing and making presentations to your class that help you learn	O	O	O	O
10. Determining how much you know about something	O	O	O	O
11. Having a voice in decisions about class activities	O	O	O	O
12. Basing new information on what you already know about the topic	O	O	O	O
13. Having enough time for you to learn what is required	O	O	O	O
14. Completing assessments/assignments that include:				
a. complicated problems	O	O	O	O
b. portfolios	O	O	O	O
c. multiple choice/short answer items	O	O	O	O
d. full-length papers/reports	O	O	O	O
15. Using technology, e.g., computers, calculators:				
a. to better understand ideas learned in class	O	O	O	O
b. as a tool to gather and organize information	O	O	O	O
c. as a tool for checking understanding (testing)	O	O	O	O
d. as a tool to communicate with your teachers	O	O	O	O

Indicate how much you disagree or agree with each of the following items.

	strongly disagree	*disagree*	*agree*	*strongly agree*
16. Truly understanding science in the science classroom requires special abilities that only some people possess.	O	O	O	O
17. Truly understanding mathematics in the mathematics classroom requires special abilities that only some people possess.	O	O	O	O

Sustaining Community

Grace Eason
Assistant Professor, Science/Science Education
University of Maine Farmington
geason@maine.edu

Mary Schwanke
Professor, Biology
University of Maine Farmington
schwanke@maine.edu

Patti Millette
Science Teacher
Mount Blue High School
patti.millette@maine.edu

Donna Wells
Mathematics teacher
Mount Blue High School
dwells@mbhs.msad9.k12.me.us

The perspectives of a variety of MMSTEC participants—university faculty members and both in-service teachers and pre-service teachers—are shared with regard to the establishment of a community of teachers and learners in western Maine. One of the implicit goals of this 5-year project was to initiate and nurture intra-campus learning communities that would include grades 6-12 teachers, university science and mathematics faculty, and college of education faculty. To a large extent this goal was successfully attained through meetings of cross-tier teaching teams, with an unexpected level of benefit for the college students, pre-service teacher candidates, who attended. As the grant comes to an end, we are challenged to find ways to sustain this important community and expand its mission to include paths by which members can discover their own inner natures as teachers.

Introduction: Grace Eason

Grant writing can, often times, be a very long and arduous process with little to no guarantee of success. When five principal investigators (PIs) from the University of Maine System collaborated to apply for a multimillion dollar National Science Foundation (NSF) Collaboratives for Excellence in Teacher Preparation (CETP) grant, little did they know that they were actually establishing an extremely important infrastructure that would change many lives. The Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC) began by focusing on three main explicit goals: recruitment, retention and professional development of mathematics and science teachers. But these were not the only goals that the investigators wanted to see come to fruition. As we better defined these actions to meet the main goals, two other supporting goals emerged to support learning communities across the state and on campuses. These goals were:

- Strengthening the mathematics/science infrastructure in Maine by providing opportunities for educators to gather around substantive issues and opportunities;
- Initiating and nurturing intra-campus learning communities that include grades 6-12 teachers, university science, technology, engineering and mathematics professors and College of Education faculty at each MMSTEC campus.

These supporting goals are the focus of this article. There were three main campuses involved in this project: the University of Maine (UM), the University of Southern Maine (USM), and the University of Maine at Farmington (UMF). In order to begin strengthening the mathematics and science infrastructure each campus hired someone to serve in a dual appointment position. Both UM and USM hired new faculty members in mathematics and mathematics education. I serve as the dual appointment in science and science education at UMF. Each person in the dual appointment position was hired to 1) help develop and administer statewide summer workshops and help coordinate follow-up activities on campus during the academic year, 2) begin to lessen the cultural gap between the Colleges of Arts and Sciences and Education by coordinating and increasing interaction among faculty and administrators, and 3) actively recruit

and advise education majors with an interest in teaching mathematics and science.

In addition to these dual appointments, the PIs also included cross-tier teaching teams as part of the grant. The campus Cross-Tier Teaching Teams (CTTTs) included science, mathematics, and education university professors, regional teachers, and pre-service teachers working together throughout the year by participating in workshops and discussions around substantive issues in science and mathematics. The CTTTs were brought together to promote communication among the different levels of educators in order to improve grades 7-16 mathematics and science education.

At UMF, these meetings were held three times each semester (Fall and Spring), with a varied format that occasionally included workshops. One meeting involved a NASA workshop on the integration of science and mathematics. At other times, the meetings would be discussion-based, where participants would have the opportunity to share their views on a particular issue—first in small groups and then with the larger group. One important aspect when organizing these meetings was to truly listen to the participants and ask for their feedback on what they would like to do, rather than force a prescribed agenda on them. There were many enlightening moments in these meetings where I thought the group would want to move in one direction, only to discover that they wanted something different. What was most helpful during the grant was the opportunity to discuss how the other regional meetings were progressing. This allowed us to then schedule and structure statewide grant events that would satisfy the needs of all grant participants. Groups from the three campuses gathered together twice a year, once in the winter for a Midyear Conference and once in the summer for a weeklong Summer Academy, both of which focused on pedagogy, assessment, and how students learn mathematics and science. Throughout the five years of this grant, what has emerged is a teaching and learning community that has become, as one teacher put it, much greater than the sum of its parts.

Throughout the five years of this grant, what has emerged is a teaching and learning community that has become, as one teacher put it, much greater than the sum of its parts.

Teaching and Learning Communities: Voices from Different Sectors

The sections below represent the voices of various participants in the UMF Cross-Tier Teaching Team—a UMF biology professor who is also one of the project's co-PIs, two regional teachers, and pre-service teacher candidates—all of whom have become part of a teaching and learning community through the CTTTs. Their perspectives provide some insight into the challenges and rewards of building such a community.

UMF Faculty Member: Mary Schwanke

When we first envisioned this project and began to put our proposal together, we recognized the need to not only increase the number and quality of mathematics and science teachers in Maine, but to improve the induction and retention of new teachers entering the profession. This need to provide some kind of support structure, ideally one that would impact both pre-service and beginning teachers, led to two important ideas: 1) hiring faculty members with joint appointments, who could bridge the gap between colleges of Education and Arts and Sciences, and 2) establishing CTTTs that would include faculty members from both colleges, beginning and master teachers from regional middle schools and high schools, and pre-service teacher candidates in mathematics and science. The implementation of these two ideas was remarkable, although not without its challenges. Reflecting back on the past four and half years, what keeps bubbling to the surface for me is the impact that our joint hire and our CTTTs have had on all those involved, and especially the faculty in Arts and Sciences and the pre-service teachers. The community that has emerged, with its sense of shared responsibility for the future of mathematics and science education in Maine, is not something I had anticipated in the days when the proposal was taking shape.

I mention the impact on faculty members in the College of Arts and Sciences because this is the category in which I fall, and the perspective that I have brought to this endeavor. Like many of my colleagues, I used to view my role in teacher preparation as one of "content provider" for future

Once we came to agreement on our deep concern for the future of mathematics/science education, and realized that making simultaneous changes at all levels would be the most effective way to break the cycle, we were able to begin to break new ground.

science teachers, and as something quite different and separate from the role played by the Education faculty. I considered K-12 classroom science teachers to be in another realm entirely, and not necessarily one that I wanted or needed to enter. And advising undergraduates who were science education majors was essentially a scheduling task, one of ensuring that the student got the right courses in the right order within the four-year program. My view of these students (and all of my students for that matter) has been forever altered.

What brought me to the project initially was my administrative role as Chairperson of the Department of Natural Sciences and some work I had done on a small Title II Faculty Development Grant in 1999, "Study of Implications of Maine's Learning Results on UMF's Curricula in Science and Mathematics". A number of my colleagues in science and mathematics had been part of this initial study, and it provided us with a connection to the K-12 world. In addition, several of these professors now had children old enough to be attending the local schools, and therefore a growing personal interest in how we were preparing future teachers.

When the MMSTEC project began to provide us with access to research on how students learn, there was genuine interest on the part of most of the faculty involved, although limited realization of the implications for their own teaching. It was the meetings with in-service and pre-service teachers that really provided the sparks that allowed ideas to catch fire. But initially, there were some barriers to overcome; several became apparent at our very first CTTT dinner meeting. First, there was a noticeable social or cultural difference between the K-12 and the higher education faculty members—essentially a feeling among the teachers of openness, gregariousness, and a need to share ideas, contrasted with an atmosphere of reserve and skepticism projected by the university professors. Second, there was the "blame game" to be worked through before we could begin to establish an atmosphere of trust and mutual respect. In essence, the university professors wanted to blame poor student performance on the shortcomings of the high school classes, while high school teachers blamed the middle level and elementary school education for the lack of preparedness of high school students. Once we came to agreement on our deep concern for the future of mathematics/science education, and realized that making simultaneous changes at all levels would be the most effective way to break the cycle, we were able to begin to break new ground.

A lot has changed since that first meeting, and there are many reasons for the success we have had at building community. It is partly because of the growing understanding and trust that comes from repeated gatherings around common concerns and partly from the increased awareness by university professors of the overwhelming challenges being faced in the K-12 classrooms. But other factors have also been key, including the fact that scientists and mathematicians tend to be open to empirical evidence. Through numerous presentations, workshops and readings, we were exposed to data showing that traditional teaching methods have not been effective for a majority of learners, and how different approaches to teaching and learning can produce better results. Another factor was the growing awareness among participants of the body of literature that exists on teaching and learning in science and mathematics, and through this, a growing understanding of the language used in the field of education. And finally, there is the enormous impact of our joint hire in science/science education. Having a facilitator and mediator with one foot grounded in the world of science and another in the world of education has been the catalyst for change that might otherwise have been too slow or too weak to be sustained. Her leadership at dinner meetings, one-on-one work with faculty members trying new strategies in their classes, and her mentoring of the pre-service teachers have all been instrumental in building a community of educators who now recognize a shared responsibility for preparing and sustaining future teachers.

Regional Science Teacher: Patti Millette

Teaching by its nature tends to be more or less a solitary pursuit. Teachers enter the classroom, close the door, and teach what they teach. It is rare for them to find quality time to get together with colleagues and collaborate, try out new activities, eat good food, catch up on good ideas, ask for help from others, or offer support and experience to someone else. However, in the local MMSTEC Cross-Tier Teaching Team (CTTT) that is exactly what happens.

Ordinarily pre-service teachers, university professors, high school and middle school teachers exist in separate communities without communication, without trust, and without fellowship. Since the fall of 2000, a small group of teachers at each level began meeting over dinners at UMF. In a series of meetings, which began with the traditional sharing of a meal, relationships began to be forged between groups based on unexpected shared experiences and good food. With the realization that we were all attempting to do essentially the same thing with the same kinds of resources and the same kinds of problems, group members began to relate as nonjudgmental colleagues instead of blaming each other for educational problems over which we separately had no control. With the growing collegiality, the number of participants grew until there was a tight group of enthusiastic teachers interacting without traditional hierarchical roles.

Regional Mathematics Teacher: Donna Wells

Finally! An opportunity to have meaningful dialogue with our colleagues AND, to participate in professional development activities which renew our love of mathematics and provide us with new and interesting materials to enhance our classrooms! In particular, we are currently introducing 'The Geometer's Sketchpad' to a variety of our classes. We received our initial introduction during an MMSTEC meeting, felt that the program could definitely have a positive impact on our students' understanding of mathematics, and were further supported in the actual purchasing of the program. Our high school now has laptop computers on carts, available for classroom use, and the mathematics department is actively introducing our students to Geometer's Sketchpad.

Another highlight of our MMSTEC meetings has been the "History of Mathematics", which allows us to share other aspects of mathematics of which many of our students are not aware. As an example, due to my renewed interest in the history of mathematics, one of my students completed a research paper on Al Jabr, an Iraqi mathematician. She then e-mailed it to her father in Iraq who shared it with his Iraqi acquaintances. The Iraqis were greatly surprised and pleased to find out that Americans had some knowledge of their contributions to the world of mathematics! Other topics which have greatly improved our abilities to reach our students are the [use of] TI-83, NASA resources, PASCO probes, mathematics-science integration, and just the time to share teaching ideas and experiences with teachers of grades 7-16. These meetings tend to provide topics for discussions back at our school.

We, the Mathematics Department at Mt. Blue High School, appreciate these opportunities and will miss them in the future. Our connections with the university faculty will hopefully continue and be beneficial to all faculty and students. Thanks for this great experience!

NSF Teaching Scholars: Pre-service mathematics/science teacher candidates

Pre-service teachers in mathematics and science, many of whom were recipients of National Science Foundation (NSF) scholarships, were regular members of the UMF Cross-Tier Teaching Team. They offered written feedback, highlighted below, showing the many benefits of membership in this group including the following: building networks for support and resources, meeting and building relationships with teachers and professors, developing a better understanding of the major issues in the teaching profession, and increased confidence and determination as a teacher.

"One of the most important things that being an NSF scholar has brought me is the huge network I have developed of teachers in Maine. I have met a lot of great teachers at dinners and conferences... and these teachers have provided me examples and guidelines that I can use."

"By attending our local dinner meetings, I was able to discuss current issues with faculty members, other scholars, and community teachers. We spent hour upon hour throwing around ideas of what is important to teach in each subject... everyone was so down to earth and willing to share their thoughts and ideas.... When I feel comfortable with my professors, I am more willing to seek help from them and that has been the most important aspect of the NSF program, bringing students and faculty together for a common cause."

"I feel I have been exposed to much more information than those students who are not involved in this program. With the connections I

"When I feel comfortable with my professors, I am more willing to seek help from them and that has been the most important aspect of the NSF program, bringing students and faculty together for a common cause."

have made with those already in the field, and the support system that I have before entering the classroom, I have a jump start on other future teachers."

"I feel myself becoming more familiar [with] the successes and problems in education today. My favorite part of being a scholar is being able to interact with science and mathematics educators at all different levels. I like to hear stories of what has and has not worked in their past experiences of teaching. I love hearing the problems that new teachers have been facing because when I get to that point I won't feel so alone. I also find the new ideas on inquiry very intriguing and I am excited to hear more about the effect of inquiry in the classroom."

"My view of science has broadened, as I have come to see how teaching biology is very different from teaching physics.... I believe because of the connections and support I have gained through MMSTEC this past year, I am going to be a very successful and lucky student teacher."

"As I come to my semester of student teaching, I am realizing the connections I have made through MMSTEC are going to be extremely valuable to me. MMSTEC dinner meetings have allowed me to meet [and] converse [with teachers], and take in ideas of what teaching mathematics and science is in the real world. Not only have I become more comfortable in an atmosphere rich with educators, but also I have gained more confidence in my ability.... My view of science has broadened, as I have come to see how teaching biology is very different from teaching physics.... I believe because of the connections and support I have gained through MMSTEC this past year, I am going to be a very successful and lucky student teacher. I know who to email with "earth science questions" or who to call when I need an idea for a mathematics lab.... Through the MMSTEC [digital] library, I know that I have several easy-to-find resources to use when I am running low on creativity. I have also gained the confidence to approach peer teachers. I feel that I will not be a 'little student' going into a 'big teachers' world' when I do my student teaching."

"As a secondary education major ... it is very easy to lose sight of why we're studying to be teachers. We constantly hear that we're going into a field where we will get no respect, no money, and will probably end up quitting after less than five years.... MMSTEC is the reassurance through all of that. It reminds me that I have always wanted to teach and that teaching does have a lot of rewards. It gives me the encouragement to move ahead in my development as a teacher and lets me know that we can fight back against the statistics and improve our part of the educational process."

"I have really enjoyed the meetings of MMSTEC. I have found them to be very informative and helpful to me as a future science teacher. It is great to hear stories from practicing teachers about what they are facing in the classroom. This information would be hard for me to find elsewhere. I appreciate the fact that there is such a supportive network available to me to turn to for advice and support. There have been many times when I have had to call upon people that I have met through this organization, and it is comforting to know that help is there."

"I am working to help create a student organization on campus to help future teachers and am joining another developing organization whose goal is to have fun with science. The meetings for scholars and local teachers have led to my making more connections to the educational community, and have shown me a large support network to help me get into a teaching career."

"MMSTEC helped ease the transition back to college for me. I thought I would feel out of place going back to college after fourteen years. But meeting other scholars and some of my professors at MMSTEC made me feel like I belonged at UMF. It's nice to recognize faces as you walk around campus.... Networking with other teachers is a great way to learn what issues I will face when I begin teaching. It also helps to know I am not alone and that there will be other teachers to help me out as a new teacher. MMSTEC has helped me realize I want to be a math teacher more than ever."

Working Toward Sustainability: Grace Eason

As collegiality grows the question remains, can these communities be sustained once the grant has ended? My responsibilities have been to facilitate our gatherings and to strengthen the relationship among pre-service teacher, in-service teachers, and university professors. Another responsibility that has emerged while working on this grant is that I now must create the space that allows everyone to share their own inner natures as teachers to go beyond content and pedagogy as they search for truth in their own teaching. Parker Palmer describes how challenging this is: "The model of community we seek is one that can embrace, guide, and refine the core mission of education—the mission of knowing, teaching, and learning. We will find clues to its dimensions at the heart of the image of teaching that most challenges me: to teach is to create space in which the community of truth is practiced (Palmer, 1998)." Currently, that "community of truth" encompasses our disciplines and how to teach those disciplines well. Eventually, over time, I hope we will be able to get to the heart of what community truly means going beyond just the "what" and "how" of teaching but getting at the heart of who is actually doing the teaching. In essence, what it means to discover our own inner natures as teachers, those individual gifts we bring to the profession that cannot be measured but influence how we interact with our students, our colleagues, the subject that we teach, and the world (Palmer, 1998).

REFERENCES

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Grace Eason is an Assistant Professor of science and science education at the University of Maine at Farmington. She teaches introductory environmental science and science education methods for future science teachers. For her environmental science students, she believes her responsibilities are to inspire them by making environmental science interesting, relevant, and applicable to their daily lives. In teaching her pre-service teachers, she believes that she must share her passion for the art of teaching science and inspire and guide them to find their own inner natures as teachers.

Mary Schwanke is a Professor of Biology at the University of Maine at Farmington where she has been a member of the faculty since 1987. Her teaching includes a human evolution course for non-science majors and courses in cell biology, animal physiology, development and comparative anatomy for biology majors. She has served as Co-PI for MMSTEC at UMF and recently developed a new course on the brain and learning.

Patti Millette is a veteran earth science teacher at Mount Blue High School in Farmington Maine. She has an M.Ed. in Science Education, an M.S. in Geology from the University of Maine, and is currently working on an interdisciplinary Ph.D. program in Geology and Science Education. Due to the lack of good qualified earth science teachers, she has developed an interest in teacher recruitment and retention issues.

Donna Wells is the Mathematics Department Coordinator at Mount Blue High School in Farmington Maine. She is a veteran mathematics teacher with an M.Ed. from USM. Her interests include improving mathematics education in public high schools, and the recruitment of quality teachers to replace those who are leaving the profession.