K-12 and University Collaboration: A Vehicle to Improve Curriculum and Female Enrollment in Engineering and Technology

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Abstract

In 1993, the State of Massachusetts enacted the Educational Reform Act to improve student performance and to increase school accountability. One of the curriculum frameworks of this initiative is titled Science and Technology/Engineering. One of the strands within that framework, Technology/Engineering, outlines standards in seven curriculum areas to be assessed at the high school level on the Massachusetts Comprehensive Assessment System (MCAS). This framework is somewhat controversial but supported by numerous surveys focusing on national needs. The movement of traditional Industrial Arts programs to a Technology/Engineering approach in both delivery and content has created a new set of problems with questions raised about the preparedness of existing Technology Education teachers to teach pre-engineering and engineering curricula. In addition there have been questions raised about the lack of female enrollment in engineering and technology classes.

This paper describes the collaboration of Amherst Regional High School (ARHS) with faculty at the University of Massachusetts and Hampshire College in addressing issues impinging the success of engineering and technology curricula. More specifically, this collaboration has focused on: reviewing and enhancing high school teacher's core knowledge of engineering design, the curricular changes made based on this study/research, and research of gender equity issues in engineering and technology curricula. Plans to recruit and retain female students in the technology/engineering area at both secondary and university levels are described; including, cross-institutional projects with an emphasis on assistive technologies and universal design, and a variety of outreach activities between institutions. A structure that provides for on-going collaboration between the local high school and area colleges is also provided.

1. Introduction

The Education Reform Act of 1993 initiated sweeping changes to public education in the state of Massachusetts. In an attempt to improve student performance and increase accountability, the Department of Education developed a set of frameworks to identify learning standards in each academic core. The assessment tools for each framework are being phased in and the first students required to pass the exams are the class of 2003. Trial questions were tested in the spring of 2002 for the Technology/Engineering strand. The Science and Technology/Engineering framework[1] includes strands for Earth and Space Science, Life Science (biology), Physical Sciences (Chemistry and Physics) and Technology/Engineering. This paper will focus on the Technology/Engineering portion of the framework. With the somewhat controversial elevation of Technology/Engineering into core curricula have come questions about teacher preparedness. Most teachers of Technology/Engineering in the state were trained as Industrial Arts teachers and they have had a tendency to specialize in one or two content areas such as; Woodworking Technology or Computer Aided Design and Drafting. The Technology/Engineering approach to the discipline tends to be a more interdisciplinary approach to the content requiring the inclusion of higher levels of science and mathematics[1-3]. At the same time, in looking at Technology/Engineering and its overriding goal of creating a technologically literate student another problem is evident. Traditional Industrial Arts/Technology Education and collegiate Engineering classes are predominantly male (faculty and students). If we truly believe all citizens need to be technologically literate then we must address this problem as well.

This paper will describe the process used to review and assess the high school teacher's needs, the collaboration and cross institutional activities between Amherst Regional High School (ARHS), the University of Massachusetts and Hampshire College to enhance the teacher's core knowledge of engineering design, curricular changes made based on the research/study and a plan to address the gender equity issue. The next few sections work toward identifying the status of the engineering curriculum and program at Amherst Regional High School as of the spring of 2002, the next section summarizes some thoughts on gender equity issues followed by the changes being implemented. An explanation of how the teacher's skills were enhanced through collaboration and the challenges faced as well as tentative evaluation plans and targets are identified.

2. Program and Teacher Assessment

In the fall of 2001 the ARHS Technology Education department completed curriculum maps[4] for each course. In doing that the department was directed to complete the maps reflecting current practice and content and to match that content with the concepts in the curriculum frameworks. With that as a benchmark the school would begin a course by course departmental review to compare current curricula to frameworks. Individuals and/or teams of teachers would then research options and make suggestions as to how to best meet the broad concepts outlined in the frameworks and then initiate a rewrite of the map and curriculum for that course. The two courses relating to this paper are the single trimester courses; Engineering & Technology I and II. Discussions were held with past teachers of the courses and teachers of similar courses in other school districts. The teacher also attended conference workshops relating to engineering sponsored by the Technology Education Association of Massachusetts, MassTec, and the STEM Education Institute.

Based on the review the teacher determined the curriculum maps and curricula needed significant adjustments to insure students at ARHS would be reasonably prepared for the Massachusetts Comprehensive Assessment System (MCAS) test. To insure student success, the following needs were identified:

- improve the understanding of design considerations/process,
- give greater exposure to planning, design standards and software,
- provide greater depth of understanding of material properties,
- improve the basic knowledge of materials processes (casting, molding etc.), and
- improvement on the usage of technical vocabulary.

The teacher in this case was trained as an Industrial Arts teacher in the early 1970's and earned a second certification in general science in the mid 1990's. He has taught a range of courses in that time but of late has concentrated on Communications Technology (formerly Graphic Arts) and Video and Audio Technology. The teacher has collaborated with mathematics and physics teachers (in and out of district) to review standards and concepts such as; force vectors, and the calculation of acceleration and force. This level of review seems to be adequate at this point for the concepts within the frameworks. The teacher's background in design considerations, design evaluation, design software, electronics, material properties and industrial processes in the best case scenario were dated and in the worst cases nonexistent. Based on those findings the teacher has developed the following plan to improve his technical background:

- earn certification/license for ProDesktop engineering design software (spring '02),
- develop technical skills and develop an appropriate instructional ProDesktop package for implementation (summer and 1st trimester of '02-'03),
- research, discuss and apply current design processes to viable classroom activities (summer of '02 and '02-'03 school year),
- research and then develop a suitable instructional package on material properties and material processes ('02-'03 school year and summer of '03), and
- attend workshops in basic electronics or work with an electronics teacher to review electronic theory and control devices ('02-'03 school year and summer of '03).

3. Technology Education/Computer Instruction Gender Assessment

Amherst Regional High School is a comprehensive high school with a current enrollment of about 1350 students in grades 9-12. Approximately 92% of the students enter college after graduation. The statistical breakdown for students taking Technology Education and Computer Instruction classes follows.

	Total TE/CI	% Male	% Female	School % M	School % F
01-02	367	87.2	12.8	53	47
02-03	405	83.7	16.3	54	56

The instructional staff for the combined departments is 92.2% male and 7.8 % female based on the number of teacher sections taught by males/females.

With female enrollment hovering at only about 15% we clearly have a problem in attracting females to this content area. The data for collegiate level programs in engineering and computer science is very similar (about 20%)[5,6]. To better understand the gender equity problem, several factors need to be considered.

4. Current Thinking on the Gender Equity Issue

The potential causes for the gender imbalance are both complex and numerous. One well-defined structure for articulating the issue is found in "Modeling Athena, Preparing Young Women for Work and Citizenship in a Technological Society"[7]. The categories and their substance rang true for all of the high school (6) and college (4) students who were informally surveyed. The "Modeling Athena" categories have been paraphrased below with the key questions.

4.1. Social Fit and Sense of Self

Is engineering something girls/young women do or is it something boys/young men do? Are they encouraged and supported to do this by parents, teachers, and peers? Do students in this class approach the work the same as their male counter parts? Is it important to them to do this kind of work? [7,8]

4.2. Classroom Climate

Are the contributions of females acknowledged and respected? Is the female perspective valued? Is the teacher aware of differences in perspective and evaluates or responds accordingly? Is praise given for the substance of female work or just for its appearance? Is the physical environment pleasing to both males and females? Are both genders treated equally (frequency of contact, method of calling on them, appropriate body language). Are girls interrupted more often than boys? Is the class climate competitive or collaborative? Is the humor in the classroom appropriate? [7,8]

4.3. Curriculum and Instruction

Is gender neutral language used in the presentation of material? Are attempts made to include female role models and perspectives? Does the instructional approach take into account the experiences, interests, concerns and learning styles of girls/women? Does the teacher know the differences in gender learning styles and the differences on how they see technology? Are the classroom activities equally of interest to males and females? Do the activities selected give an advantage to one gender? [7,8]

4.4. Role Models, Mentors and Peers

How often are female role models cited in the class for accomplishments to the field? Do you use mentors? Have you tried? Are girls and women seen as actively engaged in technology in your classes? How? Where? When? Have you actively recruited females for your classes? What have you tried? [7,8]

4.5. Messages from Counselors

Are girls (middle school and high school) informed about technology education classes? Who takes responsibility of connecting what is learned in technology education classes and technology related careers? Who takes the lead on dispelling occupational stereotypes? Is the importance of technological literacy and the relationship to career options brought up to girls as well as boys? Do counselors work with teachers to help inform and encourage girls to develop the skills and knowledge required to succeed in technological careers? [7,8]

5. Solutions and Planning for the Future

It is clear from the research that there are gender differences in learning styles, that girls/young women perceive technology differently[7-15] and in at least the short term bring a considerably different background in experiences and interests to a technology oriented class. If we truly want to raise the level of technological literacy (a primary goal of technology education) for all of our students we must make changes to our pedagogy, the activities selected and our attitudes that reflect those differences.

In incorporating learning style differences and perceptions [7,8,10, 11] of technology and interests, we could create a more equitable environment in engineering classes by changing the primary activities used to introduce or reinforce concepts. For instance, traditionally class projects in engineering/technology often focus on the artifacts of design such as engines, gears, robots, etc. rather than the motivation behind such devices such as the benefits to mankind. While their male counterparts may find the artifacts alone exciting, females often require a more holistic approach. UMass, Hampshire College and the Lemelson Assistive Technology Design Center have been collaborating for about three years in the areas of universal design and assistive technology in the Senior Design class in engineering. This year that collaboration extended to the sophomore introduction to mechanical design class at UMass (fall and spring semesters). On an individual basis, the ARHS teacher and selected students are working on a collaboration that ties into this effort that allows for mentoring, sharing of lectures, sharing of lab facilities and technical expertise.

5.1. Classroom Overview and Changes

The design activities at the high school have been changed from balsa truss bridges (1st primary activity) and robotic arms or sumo cars (2nd primary activity) to handicapped ramps for local buildings and products designed to make use of universal design principles or assistive technology devices. In both formats, students build prototypes or scaled models after working through the state adopted Engineering Design Process and the Universal Systems Model. As the course progresses students are introduced to engineering design software (ProDesktop), materials and their properties, manufacturing processes, basic electronics, lab safety and prototype/model building skills. Activities are completed in groups of three, and, while the teacher creates the groups, student preference information is gathered from the students prior to the making of group assignments. Activities are presented to the class in 10 minute presentations and a design notebook and peer and self assessment packages complete the activities.

The use of the assistive technology devices and devices making use of universal design concepts was intentionally selected to create a better motivation to capture the interests of girls/young women.[7, 8, 10, 11] This category of activities strives to take into account findings that females tend to believe that technology has the power to help others, to assist in healing and to facilitate work. The group activities were designed to reflect both the common desire for girls/young women to work collaboratively and to reflect current engineering design practice that uses design teams rather than individuals to solve engineering problems. There are numerous other types of design problems that would also respond to the desire for a more human-centered approach. Examples might include designing products that provide more ergonomic workplace environments such as comfortable seating, effective human-computer interface, appropriate lighting, etc. The move away from the robotic arm is intended to create a more level playing field from the prior experience and background position. Classes will decide on a couple of different categories within the overall umbrella of Universally Designed devices or Assistive Technology devices (such as increased mobility devices, recreational devices or reach assisting devices). Then, within that category the group will design and create a prototype to solve a problem specific to the category. This has the potential (as yet untested) to bring a wider range of previous experiences and background into the activities than the robotic arms which are primarily dependant on understanding of gears, pulleys, levers that tend to advantage the male student.

5.2. Expanding Teacher Expertise and Skills

Over the summer of 2002 the ARHS teacher worked with UMass faculty and students under a supplemental NSF grant, Research Experiences for Teachers (RET). The primary focus of that work was to research current design process within the context of universal design or assistive technology. The current and previous books used in the sophomore Engineering Design course[16, 17] were read and discussed with UMass faculty and summer students. To reinforce the concepts the teacher applied the processes to current and projected design problems used in the Engineering classes at ARHS. Readings from professional journals[18] assist in keeping the teacher current in strategies and methods. Because materials selection and industrial process choice are significant elements within the design process and decision making sequence the teacher also reviewed material properties and material processing options at a fairly basic level. The ongoing collaboration between UMass, Hampshire College and ARHS has taken the form of field trips for selected students, the teacher sitting in on selected lectures and presentations. It is also likely that technical consultations between the three entities will also be part of the mix as we try to work out the logistics of different schedules and needs.

The teacher completed the certification/license process by taking classes and completing a project using ProDesktop (engineering design software package) in May of 2002. Over the summer of 2002 the teacher refined software skills and developed an instructional package[19, 20] suitable for the timeframe available while addressing the state assessment needs (MCAS). The instructional package is being tested for the first time during the winter trimester and will be revised and tuned for the spring trimester. ProDesktop files are compatible with Pro/Engineering files and as part of the collaboration we will create a structure to provide limited student access to ProE at UMass to give students access and exposure to the higher end functions ProE offers.

Professional development in this area is a long-term project. Collaboration is a key component because most teachers of engineering at the high school level were not trained to teach the subject matter and most who teach the subject are the only teachers of that subject in their school. With that, they have no one with a knowledge base to bounce ideas off of… they teach in isolation. A combination of strategies to increase collaboration would reduce isolation. These strategies could include classroom visits, mentoring, workshops and mutual study.

6. Challenges and Opportunities

The logistics of working out a clear-cut collaboration between the colleges/university and the high school is difficult at best. The daily schedules are different, the high school is in trimesters and the college/university are in semesters and most of the high school students do not have ready access to transportation. To this point the high school teacher has sat in on selected classes and activities as schedules allow. Some students have expressed a desire to do the same in the colleges second semester. Some students and the collaborator at Hampshire College have expressed an interest in making use of the prototype building lab at Hampshire. The high school students will visit the Lemelson Assistive Technology Design Center as part of their class. The student group, Women in Engineering at UMass has expressed some interest in mentoring female high school students and is willing to participate in fairs and workshops for our school district. A concern is that the key window for creating interest in science and engineering is in the fifth through eighth grades.[21] To this point we have very limited success with teachers or administrators at these grades in giving us access to students (male or female) to advocate for science and engineering.

7. Evaluation

We plan to evaluate the interest levels, comfort levels and content knowledge of students in both the traditional Engineering and Technology classes and the modified classes. We will work with an educational assessment office at UMass to create an evaluation instrument. We have the opportunity to use the evaluation on two classes in each format this year. The results will be evaluated by the teacher, department head, principal, and secondary curriculum coordinator to finalize decisions for the next school year. Tracking the changes in the gender ratio will need to be monitored over time. The department head and administrator in charge of scheduling will collect data on initial course signups as well as retention of the students who signed up. The data collected will include the gender and race of the students.

8. Conclusions and Future Work

The primary objectives in making changes to the Engineering program at Amherst Regional High School (ARHS) were to:

- significantly improve female interest in the field over time (a goal of 3-5% yearly improvement in the next three years is the target),
- maintain or increase male interest in the field over time (based on the numbers of students signing up for Technology Education/Computer Science classes),
- increase or maintain academic content expertise (measured by MCAS scores), and
- better educate the student population about engineering in general so that they will see the filed as a problem solving creative field that creates devices and materials for the betterment of humankind.

This paper has described the collaboration of ARHS with faculty at the University of Massachusetts and Hampshire College in addressing these objectives and the issues impinging the success of engineering and technology curricula. This has included strategies for improving teacher preparedness as well as an assessment of gender equity issues in engineering/technology education with several approaches to meet the challenges of female enrollment and retention. A structure that provides for on-going collaboration between the local high school and area colleges has also been provided.

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