Engineering and K-12 Education--A Two-Way Street

Dr. M. David Burghardt, P.E.
Hofstra University

Abstract

Hofstra's Center for Technology Education was created 7 years ago to help improve the technological literacy of school children on Long Island. It has been successful in promoting change in K-12 education at the school level and the university level, and currently has a four collaborative grants involved with K-12 education. Very importantly lessons in pedagogy, and yes the design process, have enhanced the freshmen engineering program at Hofstra. This paper will briefly highlight some Center activities in the context of illustrating different types of pedagogues. The main focus will be on improving design in the introduction to engineering course with particular emphasis on authentic assessment strategies and cooperative learning within the context of a small engineering program.

The Center for Technology Education

The Center for Technology Education (CTE) was created in 1989 with the goal of improving the technological literacy of public and private school students on Long Island. To do so by interacting with school districts and providing support services in a variety of ways, through sabbatical leaves in industry for teachers, outreach programs, special seminars for teachers, administrators and guidance counselors. To involve local industry and professional societies in support of these activities and integrate university, school, industry and professional society cooperation.

An advisory board was created to translate these goals into specific objectives, such as summer programs for students and teachers that are consistent with improving technology education in the context of integrated mathematics, science and technology (MST). This is consistent with the National Council of Teachers of Mathematics (NCTM) standards, Project 2061 and the AAAS science standards and with forthcoming standards on technology education. The advisory board assists the CTE in securing finding and support of these activities for teachers and students. The advisory board draws upon all the constituencies involved in education, recognizing that perspectives are needed from the classroom, school administrators, the state education department, industry and the university.

The CTE is located in the School of Education at Hofstra. There have been other initiatives that engineering schools have had in interfacing with primary and secondary schools, but to create systemic change one must tap into the existing connections that all schools of education have with the public educational community. One must become cognizant of the myriad number of variables facing school administrators and teachers, technology education being but one. This organizational structure also gives additional support and credibility to a Center. This may require some flexibility on the part of administrators and faculty, as both may be suspicious of intentions. The CTE has been successful in this regard, in part, by asking for little and providing a service that did not exist previously.

Technology Education

Very often the question is raised. what is technology education? Computers, videos, CD-ROMs? It is not these, but the study of the human-made world. It clevelops technological literacy through activity-based study of past, present and future technological systems; their resources and processes and impacts on society. Not only do student look at technological systems from a systems view, they design and construct devices using the engineering design process. Learning about optimum solutions, criteria used to evaluate same and the imbedded mathematics and science necessary to understanding how the devices function. The above description certainly resonates with goals of engineering and engineering education.

Center Initiatives

Teachers wanted to have an activity that would be exciting to school children and have high visibility, showing technology education in a very positive light. From this the middle school magnetic levitation (maglev) contest was born. In this contest students design vehicles with permanent magnets on their bottom surface, magnets of the same polarity are on a track so the vehicles float, are magnetically levitated. Propulsion systems, such as a small dc motor with a propeller attached and powered by a battery or an electrified track, drive the vehicle down a 16 foot track in two to three seconds.

Students must submit a design portfolio which includes a sketch of vehicle and a discussion of the mathematics and science they used and learned and of course a discussion of their design. The final winners are selected on the basis of vehicle time and portfolio quality. The contest has a high visibility. There is local media coverage, press and television, and representatives from the engineering community (drawn from companies on the CTE's advisory board) act as judges. The maglev contest brings over 300 children to Hofstra from at least 20 different schools.

The contest has proven so popular, that it is being replicated in other parts of New York State. Engineering schools are teaming up with local technology teacher associations to offer the contest to middle school students in their regions. A modest grant from the Department of Energy, administered by the CTE, provides finding for initiating the contest.

The CTE always looks for collaborative relationships before entering into a activity. Not only is there strength in numbers, but credibility as well. The maglev contest is run in conjunction with three technology teacher organizations and Brookhaven National Laboratory (a member of the CTE'S advisory board); some teacher workshops have been run with the support of local industry and the CTE, and one the CTE runs in conjunction with another engineering school. In this instance, SUNY Stonybrook and the NYS Education Department with grant support from the National Science Foundation developed a high school course in technology education called Principles of Engineering (POE), similar in many ways to a freshman engineering course. During the school year, Hofstra's CTE held follow-on workshops for POE teachers.

Hofstra's School of Education has received a NYS grant to create at MA degree in MST for elementary school teachers. Of course the CTE is actively involved in this. The MST component of the MA degree focuses on creating methods courses in mathematics, science and technology education, an integrated course in MST as well as a course in computer technology. There are complementary courses required in science, mathematics and technology. The latter course will be offered in the Engineering Department's program in Technology and Public Policy.

The Center for Technology Education received a $1.6 million grant from the National Science Foundation along with industrial matching funds of $2.7 million to establish a New York State Technology Education Network (NYSTEN). This teacher enhancement grant focuses on engineering problem solving, integrated mathematics, science and technology, in the context of new pedagogical practices in cooperative learning, enfranchising women and minorities and authentic assessment. Over a period of three years, ending in August 1996, the NYSTEN Project is preparing 94 mathematics, science and technology education teacher/mentors with enhanced pedagogical, technical and leadership skills. Twenty regional teams of four to five mentors have been assembled to serve all areas of the state. ideally, each team includes two technology teachers (one middle and one high school), one mathematics teacher, one science teacher and one school/community partner. The school/community partner provides link to local business and civic organizations and serves to assist the teams in making awareness workshops to the public. The teams are conducting staff and community development workshops within their geographic regions.

Pedagogical Enhancement of Hofstra's Engineering Program

Learning educational pedagogy is not typically part of an engineering faculty member's background. It certainly was not part of mine. As part of the NYSTEN project, experts in pedagogy in a technical environment were consultants, running workshops for the mentors; workshops I participated in. The results of the workshops in cooperative learning and authentic assessment, and design and problem solving have direct application in engineering courses. The Introduction to Engineering course at Hofstra has a significant design component, two design projects are required. This design component has been greatly improved using authentic assessment techniques in the evaluation phase and the creation of the design portfolio. Cooperative learning groups are being used in several engineering courses; this would have not been possible without my workshop participation. Other faculty in engineering are becoming interested in these pedagogies and are incorporating some aspects of authentic assessment in design and laboratory courses. Technology educators are aware of is the importance of constructing the design. Virtual designs do not have the educational impact that creating a new device does, hence a characteristic of technology education is the construction of devices using the design process.

Authentic Assessment

Authentic assessment is an ongoing evaluation of what a student can do and what the student still needs to learn. It might be considered as a collection of information from various formats and modes containing both quantitative and qualitative data for various purposes. Performance assessments need to consider not only the end product, but also the process used by the student to complete the task. This can be applied to course content areas, including examinations, as well as to design projects, the area where it has been applied in Hofstra's Introduction to Engineering course.

Portfolios are a useful element in authentic assessment and a design report can be created that is a portfolio. Ideally, portfolios should encourage students to reflect on their work and consider ways to improve their performance. Importantly, students should know how the portfolios are going to be evaluated.

Evaluation guidelines, rubrics in educationaleaz, need to be specific and provided to the students at the start of the portfolio assigned or design project. The following chart describes generic assessment guidelines for a design project.

Authentic Assessment Guidelines

Assessment Scale

4 Accomplished: Work demonstrates mastery of this portion of the activity.
3 Acceptable: ‘Work fulfills all objectives of this portion of the activity.
2 Minimally Acceptable: Work acceptable, but needs minor revisions.
1 Unacceptable or Missing: Work is incomplete or needs major revisions.

Student Design Portfolio

______Notes collected during brainstorming in the report appendix.
______Notes collected during the construction of the designs in report appendix.
______Solutions to the problem statement.
______Testing and evaluation procedure for the design solutions.
______Development of the optimum design solution.
Quality of the final design--workmanship, functionality
______Creativity of the final design
______Quality of drawings and charts in the design report.
______Ability to clearly explain the design the class.
______Overall grammar and structure of the design report.

[f students work on the design during class-time, the following might be added guidelines

______Student shows consistent effort.
.______Willingness to work with other students.
______Suitable class conduct displayed

Examining the assessment guidelines, rubrics, indicates that the process is most important. These guidelines enable all students to achieve good performance for their engineering design projects even ones that are not that creative. The guidelines selected have worked successfully in freshman engineering courses and similar guidelines are used in some senior level design courses.

One of the easier pedagogues to adapt to engineering coursework is mathematics, science and technology education (MST) integration. Engineering is inherently a field that integrates all three disciplines. I have, perhaps, tried to strengthen the ties between the disciplines. In a freshman engineering course, this may prove valuable as we try to explain the curriculum and courses of study with the math and science typically learned in a disconnected fashion, One of the explicit ways the design project integrates the three disciplines is in the testing and evaluation phase of the design process. Testing needs to be repeatable and the science underlying the structure examined to explain the design functionality. To be sure, the level of engineering analysis at the freshman level is quite elementary, if it occurs at all, but students understand the need for same and the place in the design process where it occurs.

Cooperative learning is another pedagogical technique that is being incorporated into engineering courses at Hofstra. Research indicates that students are more motivated to learn and understand and retain material when they work together cooperatively. In addition, students become more accepting of each other and show an improved ability to work effectively with their peers. The guidelines that are used in this process are:

- form heterogeneous groups reflecting ethnic and gender balances.
- assign specfic roles to group members (reader, recorder, modeler, summarizer) in order to develop team skills.
- build positive interdependence (group accountability, such as a project) and individual accountability.
- encourage open discussion/exchange of ideas between students.
- offer rewards to each group based on the successes and/or the class successes use of the peer review process.

It should be noted that not all the above have to be employed in using cooperative groups in the class. Cooperative learning works very well with design projects and is used in some engineering laboratories and thermodynamics courses as well as the freshman engineering course.

Research on girls performance in science classes has shown that when forming heterogeneous groups that women benefit by being in groups by themselves if they are less than 25% of the class. I have found this to be a successful strategy in engineering classes as well. The groups are heterogeneous as well, with a mixture of student abilities, reflected by their grade point average, used in creating the groups. There are other philosophies that allow random assignment and self-selection, but the one adopted by Johnson and Johnson in creating cooperative teams for engineering classes, is the one of heterogeneous groupings. To be successful, the lessons that the groups work on must have an overall group accountability and individual accountability. There should be assessment techniques that determine both of these accountabilities. For instance, in a thermodynamics class, individuals take exams, but if the group average improves a certain amount one exam to the next, all benefit. In design projects, the overall project may have a group grade, and testing about the process may reflect individual accountability. It is also possible to have students provide group self-assessment, evaluating how each has contributed to the group and the total effort.

A quiet classroom is not a characteristic of a cooperative learning class. Students are encouraged, required, to discuss why they are doing what they are doing, justify it to others in their group and eventually to report same to the class as a whole. The teacher serves as a resource, answering questions and posing questions for students to address as they seek solutions to problems. This does take time and the number of chapters covered in the thermodynamics course have decreased compared to the traditional lecture course. However, students report that they believe they have learned the material included in the course better than in traditional lecture courses. Their performance on examinations indicates to me that in general this is true. More specifically, the floor is raised. The A and high B students will perform well regardless of the teaching methodology, lecture or cooperative learning. The performance of C and some D students shows improvement compared to traditional lecture, thus raising the overall class performance. There is a trade-off, of course, in that the higher performing students could have learned more material in the allotted time, though not the class as a whole.

Conclusion/Summary

Modern technology education instruction features design and problem solving using the engineering design process and the integration of mathematics, science and technology. There is much that can be learned by working with secondary school teachers in terms of pedagogical techniques that work well with many of today's students. These techniques, such as authentic assessment and cooperative learning, are useful in preparing students for the engineering workplace, where they work in teams and are assessed as a team and individually. Secondary teachers are also enhanced by working with engineering faculty in that the analytical skills of many teachers are quite elementary and the science background often modest as well. Engineering faculty can provide insights as to how to integrate the mathematics and science into classroom activities. The use of cooperative learning and authentic assessment pedagogues has enhanced Hofstra's engineering program as has the focus on design, particularly design where projects are constructed and evaluated.

Constructing models of design projects has been very positive. Students are allowed to make scale models, to make models out of cardboard, foamboard or other inexpensive materials as there is no budget to support material costs for the freshman course. This has not been an impediment, even though it limits some types of designs. The educational focus is on the design process, seeking an optimum solution, evaluating alternatives, not just on the final product.

Hofstra's involvement with K- 12 education remains an enriching experience for all parties.

M. David Burghardt is a Professor of Engineering at Hofstra University and Director of the Center for Technology Education. He received his Ph.D. in mechanical engineering from the University of Connecticut and is the author of nine texts and numerous articles and conference presentations.