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Part I
Trends in Pre-College (K-12) Engineering Education
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Preparing tomorrow's workforce of engineers requires that today's K-12 students learn how to become better problem solvers. This can be accomplished by engaging students in authentic, complex problems that are relevant to the world around them. Use of real-time data provides a dynamic, real-world context in which opportunities can be created for students to handle open-ended, age-appropriate problems in engineering and so obtain the experience that will better prepare them for their chosen profession.

Keywords: engineering; pre-engineering; education; problem-based learning; real-time data

This paper focuses on Engineering and Education faculty and students, and middle and high school science and mathematics teachers who collaborated on a project to investigate strategies to infuse engineering design into the Grade 7–12 curriculum using hands-on design projects. The experience in the design and classroom testing of two projects is reported. It was found that students liked the hands-on exemplars, but resisted the design aspects of the task, such as working under constraints. Boys generally reported higher self-efficacy than girls and showed different patterns of interest than girls. Projects that were not directly relevant to improving test scores were difficult to implement because of resistance from teachers and administrators.

Keywords: motivation; design; self-efficacy; hands-on projects

A growing gap between technology use and technology understanding in a consumer society creates a need to educate the general public about manufacturing—the backbone of a strong economy. This paper describes development of a museum exhibit: a visitor-centred informal education experience highlighting the principles of modern manufacturing. The exhibit architecture reflects three principal engineering activities involved in creating consumer products: product design, manufacturing and marketing/business. It explains how these fields interrelate using as an example a well understood product—a customizable pen. Each activity is implemented via two complementary components: an interactive computer game and a physical display environment, which complement each other. The results of an observational study and analysis of the data gathered through a data collection mechanism built into the game are also provided, suggesting a successful achievement of initial design goals.

Keywords: Manufacturing education; informal learning; educational outreach; museum exhibit design; educational software

Colorado State University has created a joint education–engineering degree program between the School of Education and the College of Engineering. The objectives for developing this new program include: to improve secondary education through highly qualified technology teachers; to place engineering graduates in the secondary classroom where they can encourage a more diverse group of potential engineering students at an early age; to attract a more diverse student population into engineering undergraduate programs; and to better prepare students in science, technology, engineering, and mathematics (STEM) for entering into an engineering undergraduate program. The study of engineering in education helps create a citizenry that is highly literate, disciplined, is capable of thinking critically and creatively, is knowledgeable about a range of cultures, and is able to participate actively in discussions about new discoveries and choices. Colorado State University is taking a leadership role in initiating systemic change that will positively influence the future of all K-12 education. This new joint degree program is built on new partnerships across traditional academic and disciplinary lines to innovate, cooperate and prepare highly qualified teachers.

Keywords: technology education; K-12, education; partnerships; engineering science; diversity

A partnership between Michigan Technological University (MTU) and the Western Upper Peninsula Center for Science, Mathematics and Environmental Education (http://www.wupcenter.mtu.edu) provides valuable learning experiences for K-12 students, teachers, and families throughout a five-county area, well beyond the limited staffing and budgets of typical rural school districts. Most of the programs are delivered with assistance from university students, both volunteer and paid, as well as university faculty and staff. Two programs developed through this partnership were established with NSF funding: (1) Family Science Nights where math, science, engineering, and technology (STEM) majors earn credit to develop and present lessons for K-12 students and their parents, and (2) paid internships for university STEM majors to teach after-school enrichment classes for K-12 students. The purpose of these two programs was to introduce K-12 students to engaging, hands-on activities in math, science and technology that utilized engineering applications, and provide an opportunity for STEM majors to work with K-12 students to determine if a teaching career is of interest to them. This paper will describe the benefits of the partnership that has been developed and provide a case study of the internship that was created for undergraduate STEM majors to teach after-school STEM enrichment classes to K-8 students.

Keywords: after school programs; hands-on activities; K-12 technology education; university/K-12 partnerships; engineering interns

Fifty three primary and secondary level competitions were identified through an extensive web search. They range from local to national in scope and the most popular topic is robotics. A single team may do well in a competition for several years. When the competition requires building something, winning teams typically have an enthusiastic advisor and access to money, space, tools and experts. Although many students who participate in competitions study STEM disciplines at the tertiary level, it is not clear if competitions encourage students with no initial interest to study engineering or if students interested in engineering join these competitions.

Keywords: competitions; design; K-12, engineering outreach; robotics

The purpose of this paper is to explore the extent to which curriculum initiatives in school-based design and technology education and undergraduate engineering education are converging in their intent to provide students with 'designerly' ways of knowing. The literature that describes the nature of design and designing, the nature and purposes of design and technology education in elementary and secondary schools, and the place of design in engineering education serves to frame the second part of the paper. This will describe two curriculum initiatives, one elementary and one secondary, which introduce a powerful pedagogy for teaching, learning and assessment in technology education centred on both designing and making products. The resonance of this pedagogy with contemporary trends in engineering education are explored and discussed in the third and final section of the paper. Overall, the paper speculates on the question: Is design education for engineering a continuum?

Keywords: Design education, elementary education, secondary education, curriculum development, pedagogy, progression

Part II

Contributions in: Engineering Education Research, University-Industry Cooperation, Engineering Design, Visualisation, Remote Programming, Biotechnology, Biomedical Engineering, Historical Simulation

Universities are increasingly including technology entrepreneurship in engineering education. This follows the increased expansion of the subject of engineering design education in recent decades. The literature describes important justifications for incorporating entrepreneurship education into engineering curricula, and faculty have developed courses and activities to support this approach. The Idea to Product® Competition (I2P®) is an interesting artifact of these developments, and the efforts of students, faculty members and members of the entrepreneurial community at large and the assessment of the program indicate that it is an effective educational program. I2P® represents an extra-curricular program that supplements and draws from the curriculum and traditional coursework. Led in part by student groups, the I2P® program has developed into a component of a larger culture of innovation and technology entrepreneurship at many universities. Drawing from the literature and ABET guidelines for engineering programs, the authors establish a framework for supporting engineering entrepreneurship. That framework establishes a foundation for a discussion about the program and an integrated program assessment project. The final section of the paper provides general conclusions about the program as an educational program and as part of an entrepreneurial culture, followed by an outline for future work.

Keywords: Idea to Product; I2P; international; entrepreneurship; technology commercialization; innovation.

This study sought to identify the effects on student learning of a brief 'synopsis format' laboratory report versus the lengthier 'traditional format' laboratory report. Fifty-six Iowa State University industrial technology students were randomized into one of two groups that were required to write five synopses followed by four traditional reports or vice versa. Latin Square Design analysis revealed no difference in exam scores between students who wrote synopsis reports versus those who wrote traditional reports. Exit survey results revealed that students preferred the synopsis format and perceived that the synopsis format required them to think more deeply about the content.

Keywords: synopsis; laboratory reports; Writing Across the Curriculum/WAC; writing; technical writing; professional/technical communication

Undergraduate engineering programmes often use design projects to facilitate students' experiences in solving authentic engineering problems and these design projects are frequently developed in co-operation with industrial partners. To inform mutually beneficial university–industry relationships, this exploratory study gathered data on the experiences and perceptions of industry co-operators in three undergraduate design courses, in which students completed a major design project provided by industry co-operators. Findings revealed an understanding of industry's motivations to become involved in the curriculum and identified the benefits sought, expectations of graduate engineers and student learning outcomes. Findings also revealed the critical importance of effective administration and communication in university–industry collaboration.

Keywords: design; industry co-operators; qualitative research

In this paper we describe a product dissection activity that has been developed for a graduate course on product family design to improve students' understanding of platform commonality. This past spring, the product dissection activity served a second purpose, namely, it provided an opportunity to engage students in product family design research in the classroom by having them participate in a study to evaluate the variability in the Product Line Commonality Index (PCI), a commonality index from the literature. The product dissection activity consisted of five teams dissecting and analyzing three different families of products, each containing four products. Based on their results, we identified three main sources of the variability that occur during the dissection of the products and calculation of the PCI: different levels of dissection, parts omitted from the analysis, and different values for the factors used to compute the PCI. Recommendations for reducing the variability are given based on our findings. Finally, an assessment of the students' learning reveals that the activity significantly improved their understanding of platform commonality.

Keywords: Product dissection; commonality; hands-on learning; product family design

Embedded indicators provide a direct measure of student performance against a defined curricular standard based on actual course work. When combined with other, more traditional measures of student outcomes, embedded indicators provide opportunities for validation and triangulation of assessment evidence. USMA uses established rubrics and cadet performance on embedded indicators in the curriculum to assess accomplishment of each of its ten program goals. One of these goals—continued intellectual development—reflects life-long learning, which is valued at many colleges throughout the country. This goal, however, is difficult to measure. We have overcome this difficulty through the implementation of a goal-centered general education curriculum based on established, collaboratively generated, goal standards. We identify course products, embedded in the curriculum, that are aligned with the standards and then develop instrument-specific rubrics that align the course product with the goal standard. We have used this assessment methodology to inform USMA faculty about the extent to which our students achieve the academic program goals that we have established.

Keywords: life-long learning; engineering design process; assessment; embedded indicators

A philosophy for the design and operation of an engineering design course is described. The approach not only ensures an appropriate syllabus and structure with pedagogy well suited to the teaching of design but also ensures that the course is subjected to intrinsic mechanisms that drive it to renew itself continually. The full potential of the Problem Based Learning methodology is realised. The philosophy is demonstrated in an aerospace vehicle design course that has remained effective and successful since 1946.

Keywords: problem based learning; aerospace engineering; educational strategies; design engineer; project based learning; inquiry based learning; cooperative learning; curriculum renewal; transferable skills; staff development; pedagogy; group project; multi-disciplinary; interdisciplinary; scaffolding; engineering heuristics; reflective practice; preliminary design; problem solving

Sophomore engineering students have little preparation for visualization of three-dimensional concepts such as stress and deformation. In an attempt to address this situation computer-aided learning modules using commercial engineering software were designed to improve sophomore students' visualization and conceptualization skills in an introductory mechanics course. This manuscript provides details of the instructional approach of each module and an evaluation of student performance on conceptual quizzes, homework and exams before and after module implementation. The study of the module effectiveness was based on measured efforts of students enrolled in two sections of an introductory mechanics course (EGR 232, Statics/Solid Mechanics). Both sections of the course were taught by the same professor. One section received instruction using two computer-aided engineering multimedia modules; the other section had only one module. Three conceptual quizzes were specifically designed to measure module success for all students. Results indicated that participation in the computer-aided engineering modules had a significant effect on several aspects of course performance. Potential revisions to the course in light of these and other results are discussed.

Keywords: Mechanics of materials; statics; visualization; computer-aided engineering

The study compares pairs of computer science and engineering students working distributed over several rooms with pairs collocated in one room. The task was to control and program a remotely located laser display device. In each case they were supported by a remote tutor. Distributed persons communicated over video conferencing, text chat and desktop sharing. Statistically significant correlations were found between initial knowledge and task performance ($r = 0.581$, $p = 0.019$). Setting alone was not statistically significant, but became significant when eliminating initial knowledge in a partial correlation ($r = 0.524$, $p = 0.040$).

Keywords: Collaborative learning; CSCL; evaluation; remote laboratory; programming laboratory

Biotechnology is one of the active domains in the NSF funded Engineering Research Center VaNTH (Vanderbilt, Northwestern, University of Texas, and Harvard/MIT) where educational modules have been developed. These modules cover a collection of challenges designed around bioreactors, mass and momentum transfer issues, microbial kinetics, and downstream processing, which are among core biotechnology topics. The aim of this study was to design educational modules centered on challenge-based education and to implement them in classroom settings. This paper focuses on the design and implementation of such educational modules and provides an overview of the challenges and learning activities that were developed for three specific topics that have been implemented at Northwestern and Vanderbilt Universities.

Keywords: biotechnology education; mass transfer; microbial kinetics; bioreactors

Incorporation of ethics into undergraduate biomedical engineering education requires a unique blend of engineering and biomedical ethics. We developed and integrated an ethics segment into Biomedical Computation, a required undergraduate course with strong emphasis on statistical methods. The objective of the ethics segment was to introduce basic engineering and medical ethics principles using case studies, then to provide an engineering context in which students could use these principles to construct ethical arguments and make ethical judgments. In follow-up surveys, students responded well to the case study approach, suggesting that ethics can readily be incorporated into core engineering curricula.

Keywords: biomedical engineering; ethics; statistics; Matlab

Applications of computer-aided design (CAD) techniques in the creation of teaching tools used in applied history of technology and mechanical engineering are described. We present the recovery and analysis of an old wheat mill, which used water as its energy source. The mill has been completely modelled using SolidWorks™ software, and a computer animation of the production process has been generated using 3DStudio Max™ software. The generation of CAD models and learning from simulations is the subject of the course in technology history.

Keywords: Computer-aided design, watermill, industrial heritage, computer animation, industrial archaeology, engineering education.