Providing Meaningful Hands-on Experiences in Engineering Modeling the Process with 8-12 Educators

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Introduction

During the second year of the National Science Foundation sponsored TechKnow project at Iowa State University, the Engineering Mechanics for Teachers course has been modified to meet the needs of in-service teaching professionals at sites across the state of Iowa. During the first year, the course was directed toward traditional undergraduate students in elementary education. As a result of analysis of this effort, the instructors determined that a group of practicing classroom teachers would better appreciate and adapt the engineering content for 8-12 classrooms. The new version of the course is integrated with a Curriculum and Instruction course, entitled Pedagogical Applications of Engineering Concepts in the K-12 Classroom. Each course carries one-credit. Students in the education college can use both courses for graduate credit.

The combined courses will emphasize the engineering mechanics of stiffness and deformation, stress and strain, equilibrium, buckling, bending, and material properties. A design thread is used. The information is put together in a tight package that leads to the design of pinned trusses (bridges) that culminates in the use of the West Point Bridge Designer software (available at http://bridgecontest.usma.edu/download.htm) or from the TechKnow web site under resources for teachers' section http://www.eng.iastate.edu/techknow/. The in-service teaching professionals explore the concepts and theories using discovery-learning techniques that are appropriate to the content instruction. This approach is used to provide an environment that is suitable for translation into the middle or high-school classroom. Thus, the in-service teachers learn the content in a way that is consistent with how they will eventually teach it.

Most of the course is delivered to the in-service professionals at their work or home using streaming video, WebCT, and the Iowa Communications Network, a statewide fiber optic cable network. At the end of the course, students travel to Iowa State University for a workshop where lesson plans are demonstrated and assessed. The results of the workshop, including the lesson plans are disseminated to the participants. A selected sample is available on the TechKnow website for mass distribution. The results and feedback from the students are captured during a focus group evaluation discussion that will be held in conjunction with the end-of-semester workshop.

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The TechKnow Program

The TechKnow program is a collaborative effort among the Iowa State Colleges of Engineering, Education, Liberal Arts and Sciences, and Agriculture. Its purpose is to increase the mathematics, engineering, science, and technology knowledge of in-service and future teachers so that they are better prepared to meet the classroom needs of 21st century students.

The courses have been developed explicitly for students in elementary and secondary education. A course in botany, Botany in the Classroom, was taught for the first time this past Fall 2000 semester. An existing course in entomology, Bugs in the Classroom, was taught during the Spring 2001 semester. A course is available titled "Toying with Technology," that uses Lego robots, is taught in the engineering college. As part of the TechKnow program, a comprehensive website has been developed and is continually updated to include information useful to in-service teaching professionals located anywhere. The web page URL is http://www.eng.iastate.edu/techknow.

Engineering Mechanics for Teachers

The first students in the engineering mechanics course were in-service teachers. It was offered on campus during a one-week summer workshop. At the conclusion of the summer workshop, the instructors identified an opportunity to reach a broader target audience if the content could be redesigned for delivery over the Internet. The transition to a new delivery mode was thought to have the potential to open the course to many in-service instructors who are unable to travel to campus for a week during the summer. Many teachers/learners are place bound and the Internet is a good alternative for them, allowing them to take the course during the academic year.

The content included as part of the Engineering Mechanics instruction begins with visualization of material deformation using everyday materials such as crepe paper, electrical tape, Twizzlers™, Foamies™ foam sheets, and surgical tubing to permit the students to manually stretch different materials to see the reaction both as the material is stretched and after is released. These experiments are designed to provide a qualitative assessment of material behavior. Students are prompted to make appropriate observations to guide their experiential learning. Once they begin to appreciate the qualitative differences, they are introduced to the importance of being able to quantify the material characteristics. They use latex rubber tubing, known weights, and a ruler to discover stress, strain, proportional limit, and Young's Modulus. The students are then introduced to the concept of moment and force equilibrium through the use of levers. The students begin by using a ruler and Lego™ bricks on the edge of a table to examine how moment equilibrium is established using different moment arms and weights (numbers of Lego™ bricks). This experiment provides the student the opportunity to discover the nature of moment and moment equilibrium. The concept is then extended to examine a single-span simply supported bridge with a moving vehicle load; an application that is familiar. The next concept explored is Euler buckling. The students are provided a simple lever system, as part of the kit. The lever system, shown in Figure 1, allows the student to apply compressive loads to a column. The effects of column length and cross-section shapes and dimensions are studied using this system. The students then return back to the concept of equilibrium to examine

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the internal forces in the member of a pinned truss. The method of joints is used to analyze this. The students are required to then identify tension and compression members in a truss structure. All of the concepts introduced in the course culminate in a bridge design exercise where the students are asked to select I-beams that can satisfy the tension and compression constraints in bridge structures.

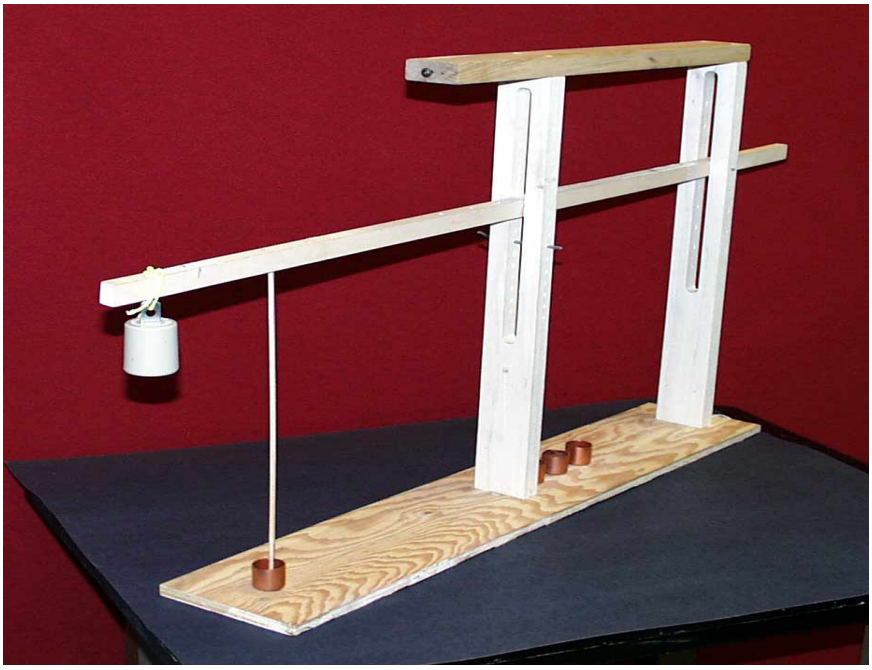

Figure 1 Level System Used for Euler Buckling Experiment

The engineering content is delivered using WebCT (Web Course Tools) over the Internet. WebCT is a set of educational tools for facilitating learning, communicating, and collaborating through the Internet. The course site contains the explanation of the engineering concepts to be learned and a description of the hands-on experiments to be conducted by the teachers at their locations to explore and learn engineering concepts. The experiments contain complex procedures that are difficult to explain in written words. Streaming video is used to illustrate how to conduct the experiments. The video and audio streams are encoded to accommodate various Internet speeds for students.

Kits containing simple every day materials and devices support experiments teachers or students conduct to discover the behavior of materials. Specifically, the kits include plastic string, electrical tape, Twizzlers, crepe paper, Foamie™, Lego™ bricks, graph paper, 3/16” and 3/8” diameter rubber tubing, balsa wood, brass and steel rods, and the lever system. The approximate cost of each kit is less than $50.00. The kits are used to visualize deformations and to discover stress and strain. A series of experiments are used to explore how Young’s modulus (E), shape, size, and length affect buckling. Similar sets of experiments are used to illustrate the effects of E, shape, size, and length on bending. These kits are shipped to each teacher prior to the beginning of semester. The experiential learning also culminates in a bridge design project.

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Two anonymous surveys will be given to get feedback concerning the delivery method. Feedback on each kit will also be solicited to determine how useful they were in establishing the foundations for the concepts. Suggestions on changes and additions will be gathered so that future kits can be refined. The results of these activities will be disseminated subsequently.

Pedagogical Applications of Engineering Concepts in the K-12 Classroom

The second part of the two-credit combined courses is a graduate-level Curriculum and Instruction course that will parallel the engineering instruction to provide an educational context to the engineering content. The in-service teachers will prepare lesson plans and explore strategies for using the engineering experiments and information to teach mathematics and science to their students. It is important to note that engineering is not a curriculum topic for the typical K-12 school district. So, teachers need to see applicable, direct connections between the engineering content they are learning and the mathematics and science topics of their classrooms.

The primary focus of this course is for the teachers to be able to analyze the mathematical and scientific thinking required by K-12 students who explore various engineering experiments. Through this approach, the teachers are able to connect the engineering content to the existing curricula, which is likely unique to each of them. During this portion of the course, the teachers explore several different learning theories related to the learning of mathematics and science. In general, the students study constructivism and the importance of concrete experiences in learning new concepts. More specifically, the teachers study the van Hiele theory of geometry learning, as it pertains specifically to the development of knowledge that seems to align well with the development of engineering knowledge.

The secondary focus of this course is for the teachers to develop engineering-related projects and lessons that will enable them to evaluate the K-12 students' acquisition of mathematics and science knowledge. This approach provides the teacher with deep insight into students' development of engineering knowledge as well as development of specific pieces of mathematics and science knowledge.

This portion of the combined course will be delivered via the Iowa Communications Network is a state-owned dedicated fiber-optic network that connects the schools, community colleges, government, hospitals, and universities in the ninety-nine counties in the state. There are 800 endpoints with high-bandwidth, full-motion two-way video capabilities. This delivery mode was selected to accommodate the two-way interaction required to discuss the pedagogy associated with delivering these learning experiences.

Future Directions and Lessons Learned

There were several lessons learned during the implementation of the web delivery. Each of the experiments and related procedures has been captured using video media and is available for use and reuse as teachers or students learn the concepts and procedures. This provides the opportunity for review and practice that isn't available in a traditional face-to-face delivery mode. Each of the lessons as well as all of the reading materials and examples are also included in the on-line WebCT environment, also providing the opportunity for review as needed. The

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instructor was especially pleased with the use of the message board feature within WebCT that allowed students to ask questions and post answers. The instructor used this feature to answer frequently asked questions so that everyone could benefit equally. The students made effective use of WebCT to work through many of the content issues and confusing points. The instructor was pleased with the success of the WebCT environment. The students have noted how much they appreciated the flexibility and convenience of the format, although the technical difficulties added extra challenges in the beginning. The technology and equipment needed for the Internet delivery presented the biggest problem. The instructors are considering how to address this in the future and may try CD Rom delivery as an alternative. Aside of the technical challenges, the instructors were somewhat surprised by the amount of additional preparation required to produce meaningful learning experiences in the Internet environment. These efforts can be leveraged as material is reused in the future.

The sessions delivered via two-way video over the Iowa Communications Network provided an interactive atmosphere that supported the web-based delivery especially well in the beginning when the in-service teachers were getting used to the technology and dealing with issues surrounding the delivery methods. The instructors will keep this aspect of the blended delivery and possibly add more sessions during the first weeks of the course.

The instructors will carefully assess both the learning and the delivery modes throughout the spring semester and explore opportunities for future development as well as refine the original course as necessary. These results from this spring will be presented subsequently. Due to the high level of interest from the in-service teachers, this course will be refined and delivered in the future. The framework and delivery mode will be adjusted to accommodate the learners as we learn more about their needs.

Biographies

LOREN ZACHARY
Loren Zachary is Assistant Dean in the College of Engineering at Iowa State University. For the past twenty-five years he has taught courses in engineering mechanics including Mechanics of Materials and Experimental Stress Analysis. He received the M.M. Frocht Award (educator of the year) from the Society for Experimental Mechanics. He is a Co-Principal Investigator on the TechKnow program.

JANET M. SHARP
Janet Sharp is an Associate Professor of Mathematics Education at Iowa State University. She holds advanced degrees in mathematics, education, and mathematics education. She taught middle school mathematics, community college mathematics and teaches collegiate mathematics education. She conducts research in the area of effective teaching, has won two university-level teaching awards, and was named a Wakonse fellow for teaching excellence.

REBECCA SIDLER KELLOGG
Rebecca Sidler Kellogg recently became the Director for Engineering Distance Education at Iowa State University (ISU). She is also an adjunct assistant professor in Aerospace Engineering and Engineering Mechanics at ISU. Her research interests include engineering design, learning and education in engineering, and learning environments appropriate for life learners.

BARBARA ADAMS

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Barbara Adams is a Teacher-In-Residence at Iowa State University. She received a B.S. degree in Education from the University of Nebraska in 1979 and a M.S. in Effective Teaching from Drake University in 1998. She has 20 years of teaching experience in K-8 classrooms, received an Excellence in Education award, and is a member of the Woodrow Wilson National Science Foundation Leadership Program.

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