Engineering New Curricula for Technology Education

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Abstract

The University of Maryland, Baltimore County (UMBC) and the University of Maryland, Baltimore, in cooperation with Technology Education teachers from area high schools and industrial consultants, are addressing the need to increase the awareness of and interest in career opportunities in engineering and technology by developing modular Technology Education curricula that use authentic real-world engineering applications and hands-on experiences to build students' problem-solving skills and technological literacy. The project is aligned with the International Technology Education Association (ITEA) Standards for Technological Literacy as well as the National Science Standards.

Specifically, we are developing five case studies to be presented in both web-based and CD format that use real-world examples and practicing engineers to introduce students to engineering design, analysis and decision-making processes. Inquiry-based learning with hands-on experiences will be used to maximize student interest and understanding. Data will be collected to evaluate how interactive, authentic, problem-solving simulations impact and facilitate student learning. In-service training with the curriculum for Technology Education teachers will be provided prior to classroom use. In addition, a specific objective of the project is to increase the involvement of women and other underrepresented groups in engineering and technology by providing female and minority role models in the classroom and developing case studies that encourage interest and participation by all groups. Therefore, interest in and awareness of engineering and technology-based careers will also be assessed prior to and after exposure to the new curricula.

The first module, "Engineering and Health Care", is near completion and to will be tested by high school technology education students in spring 2005. A case study of hemodialysis is the focus of the module, which is comprised of a number of parts. First, students are introduced to a dialysis patient and his doctor (via a professionally produced video segment), who explain his disease and experience with the procedure. The students then go through a series of hands-on activities, demonstrations, and computer simulations where they learn about the factors that

influence dialysis. Assessment tools are built into the module and provide electronic feedback to students as they proceed through the module. After successful completion of the content portion of the module, the patient issues an “engineering challenge” to student teams to design and build a hemodialysis system that meets specific performance criteria. The students then use the computer module to run a mathematical model of a hemodialysis system in which parameters are varied and performance evaluated. Based on results with the simulator, students choose how to build their system. The systems are then built, tested and evaluated, providing students with a true design experience. The final segment of the module provides short video segments with the doctor, a dialysis technician and an engineer each discussing his/her role in the implementation/design of dialysis procedures. Career information is also provided.

Introduction

While the National Science Foundation predicts employment for engineering occupations to increase by an average of 20% between 1998 and 2008, overall enrollments in engineering have decreased since 1992 [1,2]. These opposing trends are expected to create a shortage of engineers in the work force within the next decade[3]. Further, while the overall U.S. labor force is becoming increasingly diverse, women comprise only 9% and minorities only 4% of the engineering workforce [1, 2]. It is therefore imperative to attract higher numbers of students, particularly women and underrepresented minorities, to engineering and technology-based careers. For success, these students must be academically prepared to meet the challenges of an engineering education

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To meet the above challenges, we have initiated a curriculum development project in cooperation with industrial consultants and Technology Education teachers from Baltimore area high schools. The new modular curriculum units use authentic real-world engineering applications and hands-on experiences to build students’ problem-solving skills and technological literacy. The content is aligned with the International Technology Education Association (ITEA) Content Standards for Technological Literacy published in 2000 and corresponding new standards in the State of Maryland issued in 2003. Modules also align with the National Science Standards to broaden potential use.

The curriculum materials will consist of five case studies in both web- and CD- format**.** To increase the interest of women and other underrepresented groups in engineering, the case studies will feature women and minority professionals in video segments. The curriculum will also promote active participation by all groups by including of a variety of hands-on and group learning activities. The effectiveness of the modules to increase technological literacy as defined by the ITEA and to increase the awareness of and interest in engineering careers will be investigated. Finally, in-service training and professional development for Technology Education teachers will be offered to provide an overview of and training with the curriculum and case studies prior to classroom use.

Module Design

The project will create a set of five interactive computer modules to be used as supplemental curricula in a Technology Education program. The stand-alone modular format will allow for the adoption of a single module or the entire series. In addition, the curriculum is flexible and could be implemented across several courses or integrated into a single design-oriented course. Each interactive learning module will focus on engineering decision-making while exposing students to "real world" engineering problems and applications. The modules integrate hands-on activities with an inquiry-based approach that concentrates on critical thinking, problem-solving and conceptual understanding.

A total of five modules will be developed: Engineering in Health Care, Engineering in Flight, Engineering and the Environment, Engineering in Communications and Information Technology, and Engineering Energy Solutions. Each module will follow a similar "template", beginning with a short video of practicing engineers discussing a current "real-world" design problem, its constraints and the need for overcoming the challenge. The goal of this format is to help students see the relevant uses and application of the knowledge they are gaining in the problem-solving exercises.

Students will then be given a related "Design Challenge". The "Challenge" will present student teams with an open-ended design problem along with technical specifications for the design. Short hands-on exercises will follow, to give the students a "feel" for what physical parameters might be important to the design. The students will then proceed through the interactive case study computer simulation that follows the traditional approach of an engineer. It will begin with the students learning about basic scientific laws and principles that will affect their design, including terminology and a review of appropriate topics that apply to the given case. The students will then use the computer module to make decisions regarding their design and use mathematical models to predict performance. As such, the computer simulation will allow the students to iteratively assess various designs in order to choose the final design parameters. The teams will then build, assemble, test and evaluate the performance of a prototype. At the end of this "hands on" part of the project, the students will return to the computer module to find out about "real world" applications of what they have learned, complete with career information and video clips of practicing engineers discussing their work.

The Engineering in Health Care Module

Engineering in Health Care is the first module to be developed and focuses on a hemodialysis case study. When the kidneys fail, the body requires artificial kidney support to filter waste products and excess water from blood in order to sustain life. One such way to provide kidney support is through hemodialysis. In this procedure, a patient's blood is passed through an apparatus that removes impurities and water via diffusion and osmosis through a semi-permeable membrane before returning the blood to the body. This case study was chosen based on its clear relation to engineering principles (diffusion, mass transfer, fluid mechanics) and engineering design. In addition, kidney failure can affect teens and dialysis is a common procedure of which most students are likely aware.

Prior to initiation of the module, student groups engage in an “Engineering Challenge”. In this hands-on exercise, teams are required build an apparatus to separate Rice Krispies from a mixture of 10 different breakfast cereals of different sizes and shapes using only given commonplace materials (Figure 1). The purpose of this exercise is to initiate student thinking as to how materials may be separated and purified. In addition, the exercise provides an opportunity to pre-assess the extent to which students apply a rational design process.

To begin the online case study, a young man who regularly undergoes hemodialysis introduces himself and his doctor and describes both his disease and his treatment via a professionally produced video segment. Students then enter a tutorial that presents content about the function of kidneys and describes how dialysis works. The tutorial then introduces the student to diffusion (both simple and selective) and the parameters that affect the phenomenon. Interactive animations allow the student to manipulate parameters such as temperature, molecular size and concentration and visualize the effect on diffusion (Figures 2 and 3). For the case of selective diffusion, the student may also manipulate membrane porosity, pore size and surface area using animation. Hands-on activities that demonstrate these effects are also included (Figures 4 and 5). Throughout the tutorial, short quizzes test student understanding of the content. A student’s path through the content material is based on responses to quiz questions, with supplemental and/or remedial content added for students who are having difficulty. In some cases, the quiz asks the student to develop the correct proportionality between diffusive flux and various parameters. In this way, students identify which variables are directly or inversely proportional to flux. This type of exercise introduces the use of mathematics to describe diffusion. In addition, it provides the students with a basis from which to consider the effect of various parameters on the efficiency and effectiveness of dialysis system.

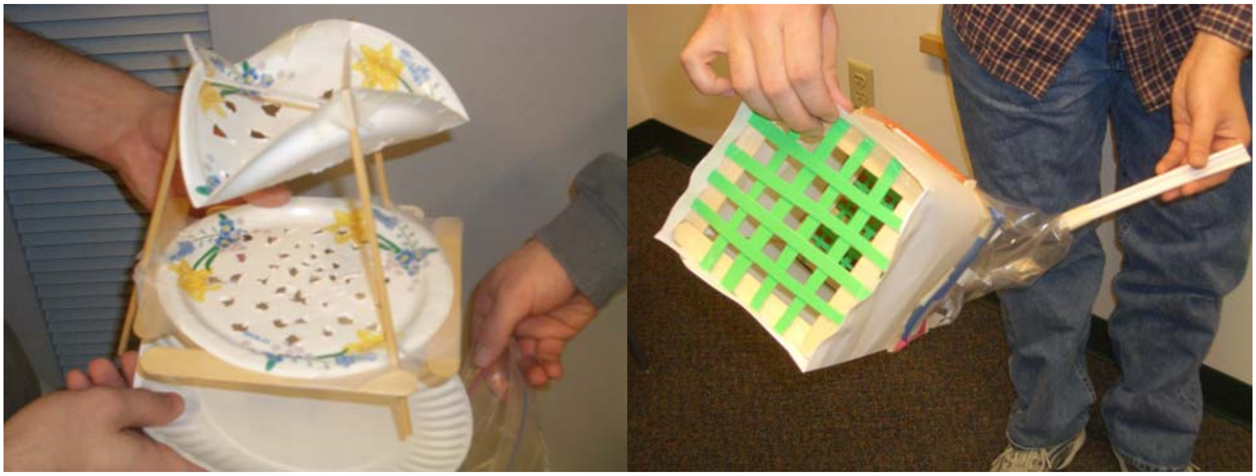

Figure 1: Pre-module “Engineering Challenge”

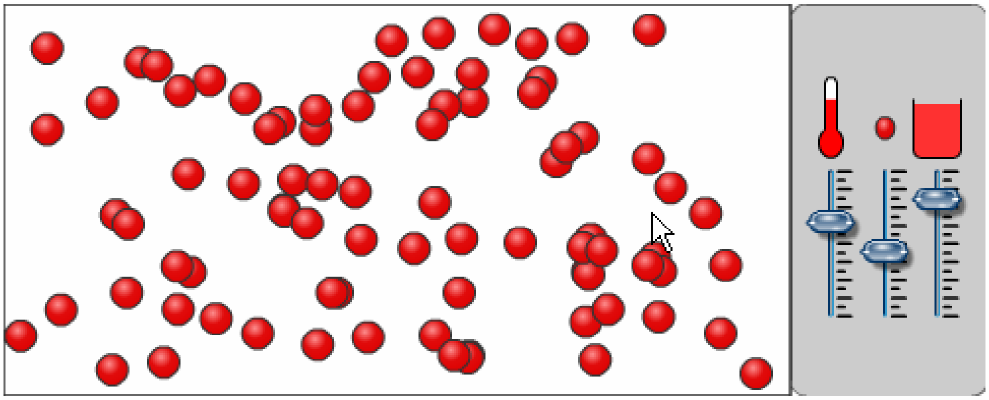

Figure 2: Interactive animation of simple diffusion. Students are allowed to move the slide bars to visualize how varying temperature, molecular size or concentration affects simple diffusion.

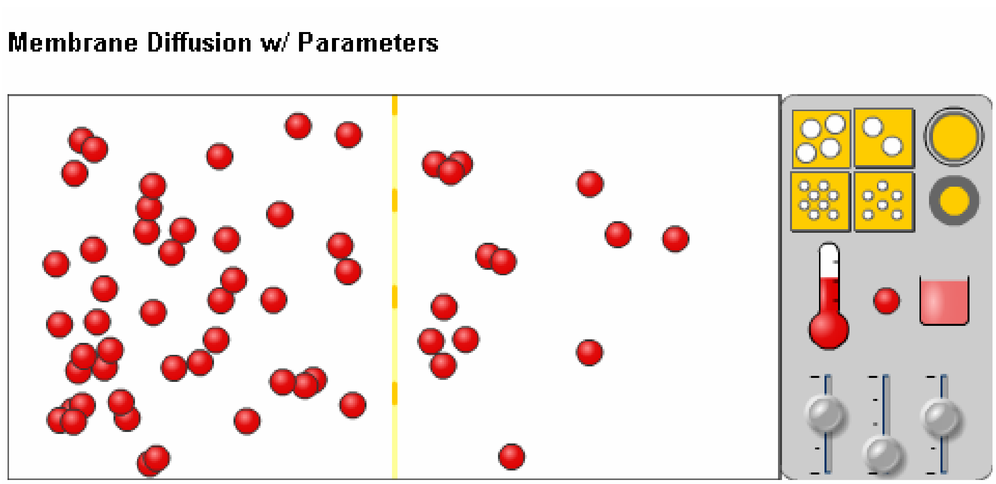

Figure 3: Interactive animation of selective diffusion. In addition to varying temperature, molecular size and concentration, students are allowed to manipulate pore size, porosity and surface area to visualize the effect on selective diffusion.

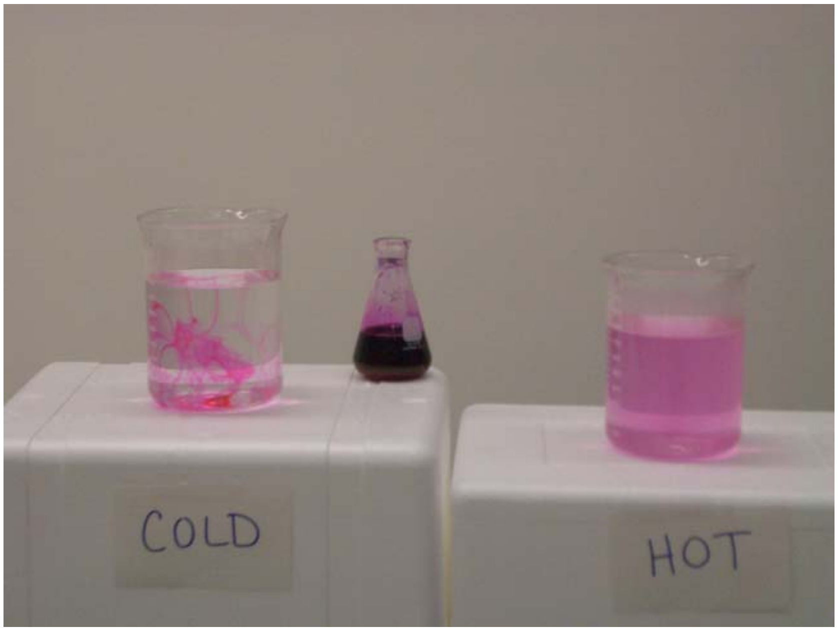

Figure 4: Hands-on activity demonstrating the effect of temperature on diffusion.

Figure 5: Hands-on activity demonstrating selective diffusion. In this activity students observe the diffusion of a yellow dye out of artificial "blood".

At the conclusion of this portion of the module, the student is introduced to fluid flow and the Bernoulli equation. A hands-on exercise demonstrates the relationship between the height of a draining tank and the velocity of the exit stream. This content is then related to the ideas of co-current and counter-current flows in hemodialysis design. An animation showing these different flow patterns is included (Figure 6). To conclude the tutorial part of the module, the students take an online quiz to measure understanding of content.

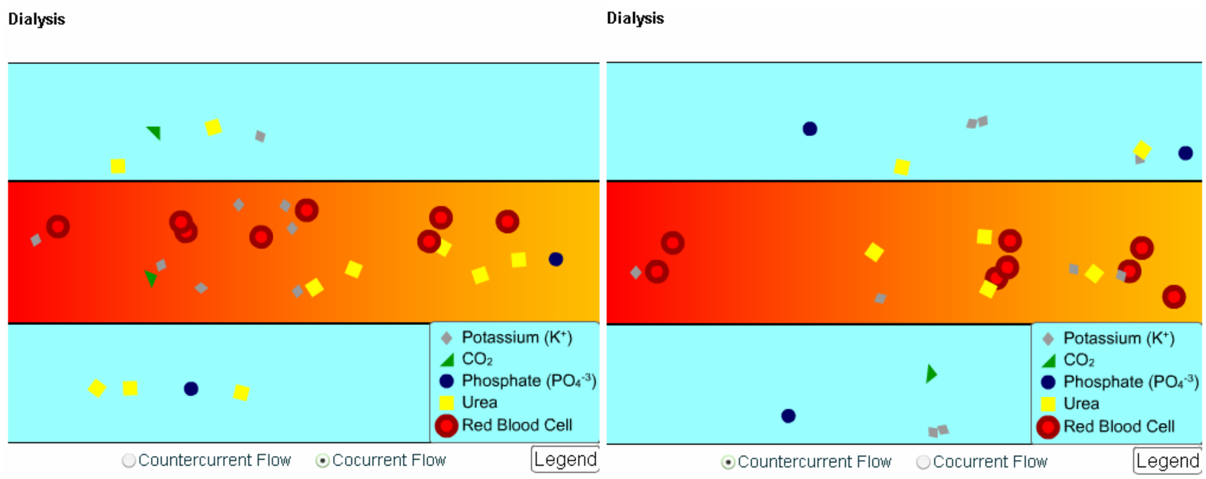

Figure 6: Interactive simulation demonstrating the affect of contact direction on diffusion through a membrane. Cocurrent is on the left and Countercurrent flow is on the right.

The students then enter a simulation tutorial that introduces the design process. Following this introduction, the hemodialysis patient (via video clip) presents a challenge to student teams to design a hemodialysis apparatus that will meet specific performance criteria given specific constraints. Students then mathematically simulate a hemodialysis design using an equation that describes the design efficiency. By varying parameters such as membrane pore size and surface area, and blood and dialysate flow rates the student can investigate what designs are the most efficient. Co-current versus counter-current designs are also considered. As a final step, cost is introduced as a critical parameter. When the students have identified what they believe to be a "winning" combination of parameters (i.e. a design that gives relatively high efficiency for relatively low cost) they are instructed to build and test their hemodialysis system. Initial testing of the design challenge with UMBC undergraduates demonstrated a wide variety of operable systems that could meet the design specifications. (Figure 7).

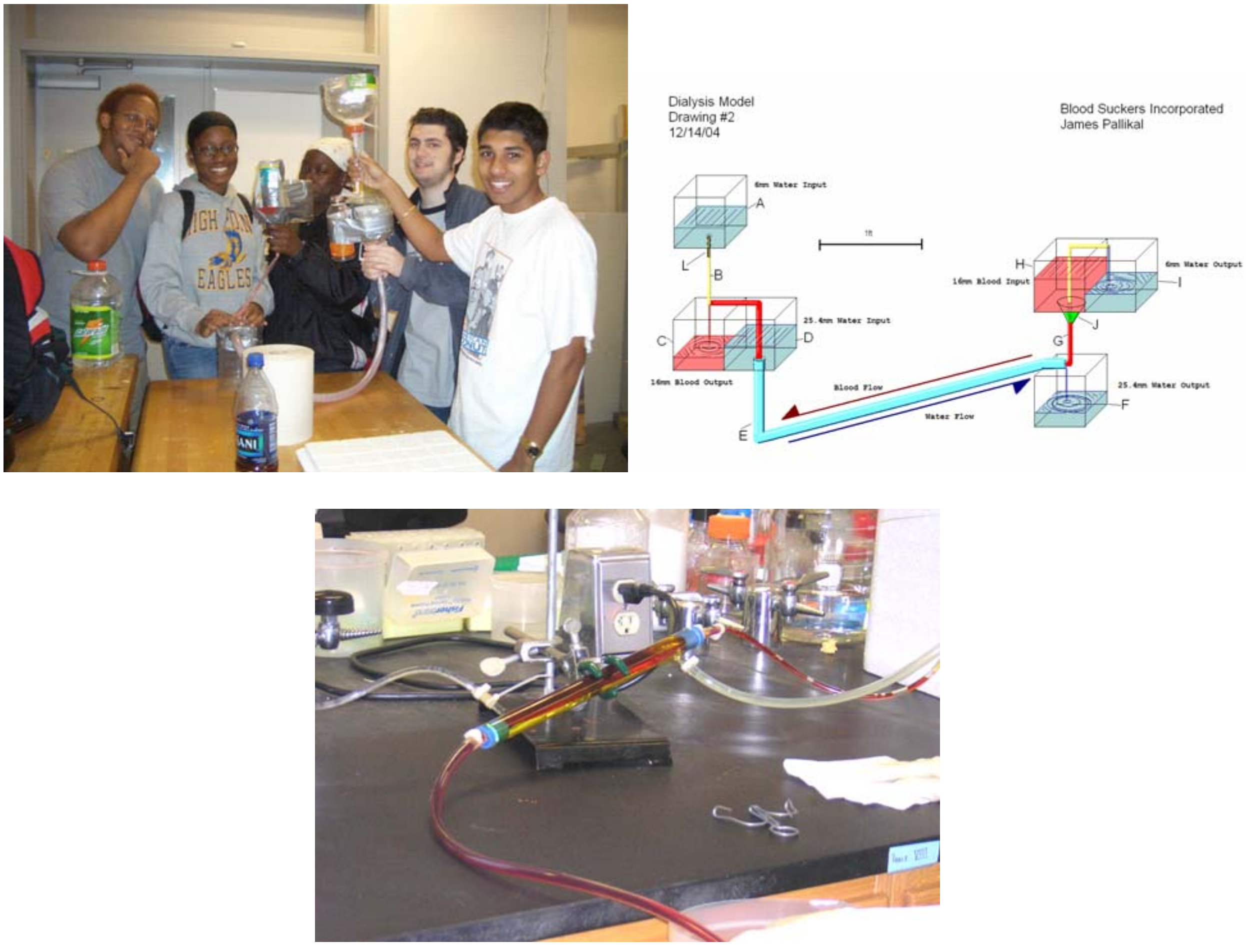

Figure 7: Examples of design solutions for a hemodialysis apparatus.

After the students have completed the entire module, groups are issued a final "Engineering Challenge". In this hands-on exercise, teams are asked to design a process to separate colored sand from a mixture of cornstarch, salt, gold glitter, metal filings, rice, BBs, and small irregularly shaped metal chunks using only given commonplace supplies (Figure 8). This follow-up activity is used to assess the groups' use of the engineering design process when faced with a complex separation task and limited time. Results from this post-assessment are compared to results from the initial "Engineering Challenge" in order to measure whether students have learned to apply the process of engineering design.

Figure 8: Post-module "Engineering Challenge"

Analysis

An assessment and evaluation team from Loyola College is working with the project team to analyze the data collected from the modules. The team is assessing how the problem-solving simulations impact student learning as well as student interest in engineering. The impact on student learning of each module and the collective of modules will be assessed. The analysis team will use the data collected from online assessments as well as survey instruments and focus groups to evaluate module effectiveness.

Future Work

The Engineering in Health Care module will be piloted in four Baltimore area high schools in Spring 2005 and teachers in the state of Maryland will begin receiving professional development in Summer 2005 in order to implement the module in their classrooms in the 2005-2006 academic year. Development of the Engineering in Flight and Engineering Energy Solutions will commence in parallel with these dissemination activities.

Bibliographic Information

1. National Science Foundation, 2000. Women, Minorities, and Persons with Disabilities in Science and Engineering.
2. National Science Foundation, 2000. Science and Engineering Indicators.
3. D. E. Hecker, 2001. Occupational Employment Projections to 2010. *Monthly Labor Review Online* 124.

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