2006-2432: "ENGINEERING IN HEALTH CARE" MULTIMEDIA CURRICULUM FOR HIGH SCHOOL TECHNOLOGY EDUCATION

Sara Titus, University of Maryland-Baltimore County

Sara Titus is a graduate student in the Chemical and Biochemical Engineering Department at UMBC. She received her Bachelors degree from UMBC in May 2005.

John Raczek, University of Maryland-College Park

JOHN W. RACZEK is a Web Developer in the Office of Medical Education at the University of Maryland School of Medicine. His work focuses on developing software systems for education with an emphasis on simulation.

Bruce Jarrell, University of Maryland School of Medicine

BRUCE JARRELL is Senior Associate Dean and Professor of Surgery at the University of Maryland School of Medicine. He has been an active teacher of medical students and residents of surgery since 1980 and has received the Clinical Teacher of the Year numerous times. He received his undergraduate degree in Chemical Engineering from the University of Delaware.

Carolyn Parker, George Washington University

CAROLYN PARKER is an Assistant Professor and lead faculty member to the Secondary Education Program in the Graduate School of Education and Human Development at the George Washington University. She holds a BS in Biology, MA in Teaching and PhD in Curriculum Instruction and Science Education. Dr. Parker's research interests are in the achievement of women and underrepresented groups in science/technology.

Taryn Bayles, University of Maryland-Baltimore County

TARYN M. BAYLES is a Professor of the Practice of Chemical Engineering in the Chemical and Biochemical Engineering Department at UMBC, where she teaches the Introduction to Engineering Design and Chemical Engineering Analysis courses. Her research interests include engineering education and outreach, and has received funding from NSF in excess of $3M over the last three years.

Julia Ross, University of Maryland-Baltimore County

JULIA M. ROSS is an Associate Professor in the Chemical and Biochemical Engineering Department at the University of Maryland Baltimore County. Her technical research interests are in the area of cellular engineering. In particular, her work focuses on bacterial adhesion to physiological surfaces. In addition, she maintains an active research program in curriculum development with a focus on workforce development.

"ENGINEERING IN HEALTH CARE" MULTIMEDIA CURRICULUM FOR HIGH SCHOOL TECHNOLOGY EDUCATION

Introduction

This instructional materials development project, funded by the National Science Foundation, seeks to provide new curricula that incorporate hands-on experiences and inquiry-based learning with 'real world' engineering design exercises to target the ITEA Standards for Technological Literacy as well as national standards in science and mathematics. In addition, in-service training with the curriculum and professional development opportunities for Technology Education teachers is provided prior to classroom use. A specific objective of the project is to increase the involvement of women and other underrepresented groups in engineering technology by providing female and minority role models in the classroom and developing case studies that encourage interest and participation by all groups.

The new materials have been titled "The **INSPIRES** Curriculum: **IN**creasing **S**tudent **P**articipation, **I**nterest and **R**ecruitment in **E**ngineering and **S**cience". In total, five stand-alone modules will be developed covering a wide spectrum of engineering applications relevant in today's society. The first learning module, "Engineering in Health Care: A Hemodialysis Case Study", has been completed and is currently available for adoption. To date, the module has been tested in a number of technology education classrooms and a summer professional development workshop has been held. In this manuscript we will describe the "Engineering in Health Care" curriculum unit and will present preliminary data related to student learning, student attitudes and teacher interest.

Background and Rationale

There is an urgent national need for new curricula in science and technology education. Indeed, a new report by the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine entitled "Rising Above the Gathering Storm" specifically calls for the development of rigorous new K-12 curriculum materials to improve science and mathematics education as a highest priority action[1]. In 2004, China and India together graduated ten times more engineers than the United States[1] and U.S. enrollment in engineering disciplines is declining[2]. However, between 1998 and 2008 the National Science Foundation predicts that employment opportunities for engineers will increase by twenty percent[3]. These diverging trends are expected to create a shortage of engineers in the U.S. workforce in the near future[4]. While women and minorities comprise an increasingly large percentage of the total workforce, minorities comprise only four percent and women only nine percent of the engineering workforce[2, 3]. If the United States is to remain technologically competitive in the 21st Century, current trends must change[1]. Greater numbers of students must choose to enter engineering disciplines and must be adequately prepared in high school to be successful in this endeavor. It is with this perspective that the INSPIRES Curriculum is being developed.

The INSPIRES Curriculum specifically targets three educational Standards for Technological Literacy put forth by the International Technology Education Association (ITEA). Each is related to engineering design.

Standard 8: Students will develop an understanding of the attributes of design
Standard 9: Students will develop an understanding of engineering design
Standard 11: Students will develop abilities to apply the design process

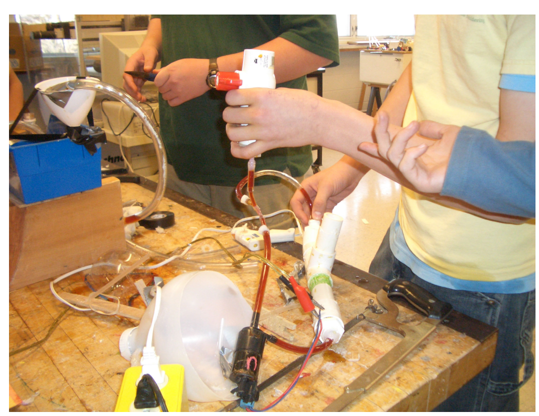
The goal of the curriculum is to develop standards-based materials that are rigorous, novel and effective at promoting learning, yet are fun and interesting for high school students. Great care has been used to generate materials that encourage the interest and participation of women and minority students. In addition, the curriculum is designed to be low cost so that it will be accessible and affordable for all school systems to acquire. Support for teachers is also a priority and is addressed through professional development workshops and the development of a substantive teacher manual to accompany the curriculum.

Module Design

The design of the module entitled "Engineering in Health Care: A Hemodialysis Case Study" is representative of the INSPIRES Curriculum. The overall focus of this four-week unit is on the engineering design process and this theme is interwoven throughout. An array of instructional methods is used to present the material in an effort to target a variety of learning styles. In particular, hands-on activities and online tutorials, interactive animations and simulation are utilized. Both individual and group/team work is included. The module is currently available for adoption by teachers who have attended a professional development workshop.

Assessment rubrics are integrated into the learning module in order to evaluate the effectiveness of the materials. Prior to using the curriculum, students take an online Interest and Attitude Questionnaire and Pre-Assessment to establish baseline attitudes and knowledge. In addition, a short (45 minute) team design challenge is used to evaluate the extent to which student teams are using the engineering design process prior to exposure to the curriculum. Upon completion of these activities, the students begin the unit.

Students are introduced to a dialysis patient and her doctor through a professionally produced video segment. The purpose of this segment is to provide societal context for the module topic. Students then go through a series of hands-on activities related to hemodialysis, mass transfer, and fluid flow. The goal of these exercises is to get the students thinking about the topics relevant to hemodialysis and to get them actively involved. Next, students go online individually and are presented with a challenge to design an efficient and inexpensive hemodialysis system using everyday materials. The online portion of the curriculum then continues with a content tutorial focused on the design process and on the scientific basis for hemodialysis. Throughout the tutorial the design cycle reappears reminding the student of the relevance of a particular exercise. The experience is inquiry-based, with the design challenge motivating the need to understand the specific content. Interactive animations are used



throughout the online content to illustrate key concepts, such as how various parameters affect diffusion. Each student then mathematically simulates a hemodialysis system online to predict the performance. This allows the student to manipulate a variety of parameters to determine which combination is likely to yield a successful design. After a student successfully completes the computer simulation, the patient and doctor (via video segment) discuss their visions of hemodialysis for the future and reiterate the challenge to design and build a hemodialysis system that meets performance criteria. Student teams subsequently build, assemble, test and evaluate the performance of the prototype that they create. To focus on communication skills, an oral and/or written analysis of the final design is also required. At the end of the design project, the students return to the computer module to see an inspirational video of engineering and medical students discussing why they chose their particular fields of study.

To finish the curriculum, student teams perform a second mini design challenge to evaluate whether the design cycle is being followed now that students have experience with the larger design project. Individual students then go online to take the Interest and Attitude Questionnaire and Post-Assessment (identical to the Pre-assessment plus additional questions). A Post-Module Questionnaire is also included to determine which portions of the curriculum students feel are most effective.

Results: Analysis of Student Learning and Attitudes

The Engineering in Health Care Module was adopted in several Maryland schools during the spring and fall of 2005. Five trials were run in technology education classrooms with 4 different instructors. These classrooms included 69 students ranging from Freshmen to Seniors with varied educational and cultural backgrounds. Data collected from initial tests led to a restructuring and refining of both the module tutorial and assessment instruments. Therefore, the data presented herein represents results from two of the five trials (in two different schools). Since testing is ongoing, additional data will be incorporated into this manuscript in the final version.

To measure learning, students were given an online assessment consisting of multiple choice and matching questions before and after completing the module. The assessment questions can be broken down into two categories: scientific concepts and design concepts. Scientific concepts include a range of topics, some of which were likely covered in previous courses (e.g. molecules, membranes, solutes) and others more specific to hemodialysis (e.g. diffusion, concentration gradient, dialysate). Student scores on scientific content showed an average increase of $8\% \pm 3\%$ (see Figure 1) with the most significant increases displayed on questions related to topics specific to the module. For example, on questions where the students were asked to define hemodialysis and dialysate the percent of students correctly answering the questions increased by 39.1% and 30.5% respectively from pre-test to post-test. Further analysis of these two problems revealed that 100% of students who answered the hemodialysis question incorrectly on the pre-test, answered this question correctly on the post-test and 70% of the students who answered the dialysate question incorrectly on the pre-test answered this question correctly on the post-test. In summary, while the overall increase was somewhat low at 8%, this is likely due to high initial scores on the pre-assessment. For problems for which the score was initially low, much more significant increases in learning were observed. These early results suggest that the online delivery of complex technical content is feasible and can lead to significant student learning.

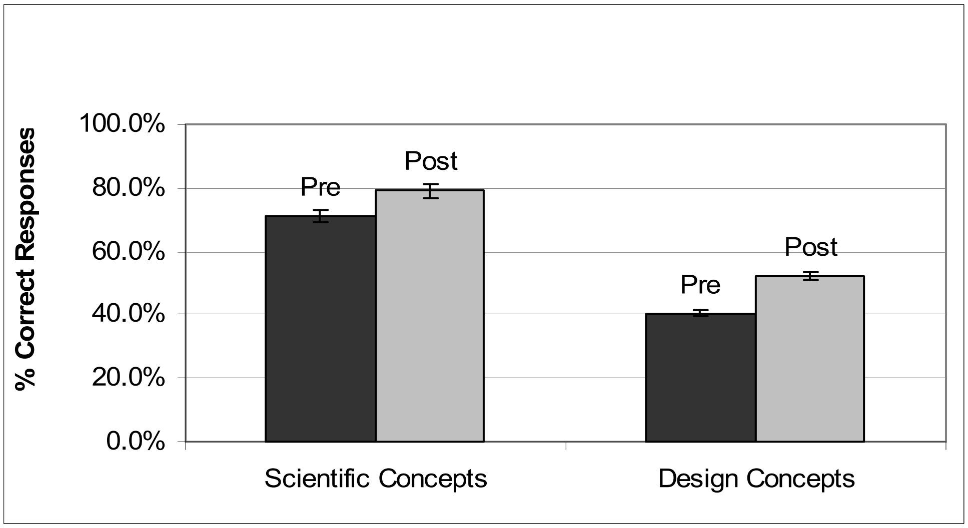
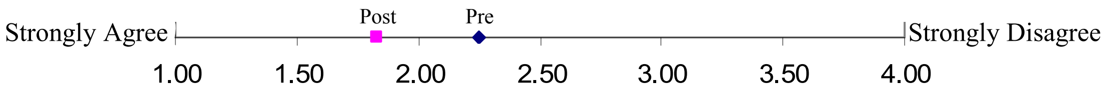


Figure 1. Student learning of scientific and engineering design concepts presented as mean assessment scores ± standard error.

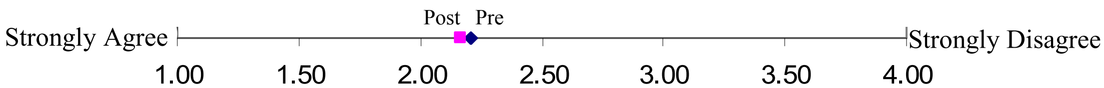
The assessment instrument developed to test student knowledge of design concepts consisted of six brief constructed response (BCR) type questions. Several of the questions ask the student to give real-life examples or to relate a design concept to a real-life scenario. Scoring of these questions was based on a rubric that listed key points student responses should include. Due to adjustments made to question wording between trials, data from only 1 trial are shown in Figure 1. Preliminary data demonstrate that student knowledge of design concepts improved from pre to post test, with scores increasing 12% ± 5%. In particular, on the question pertaining to the iterative nature of the design process, 80% of students scored higher in the post versus pre assessment. Similarly, 29% of students increased their ability to correctly order the steps in the engineering design process after exposure to the curriculum. These improvements demonstrate that this module is effective at targeting ITEA Standard 8: Understanding of the attributes of design. However, overall average scores on design concepts were lower than anticipated. This may be due to the fact that initial field tests were done in courses where students had already been exposed to engineering design. It is expected that scores will increase more substantially in courses where students had no prior exposure. Expanded field tests will likely determine whether this is the case. Additional trials are being carefully monitored to determine whether this is a consistent outcome.

Students also took an Interest and Attitude Questionnaire before and after completing the module to poll their perceptions and expectations of engineering and technology. The Questionnaire consisted of 15 statements conveying opinions on engineering, and technology. Students were asked to rate their agreement with the statement on a scale of 1 to 4 (1=Strongly Agrees, 2=Agrees, 3=Disagrees, 4=Strongly Disagrees). Mean student responses for selected questions appear below.

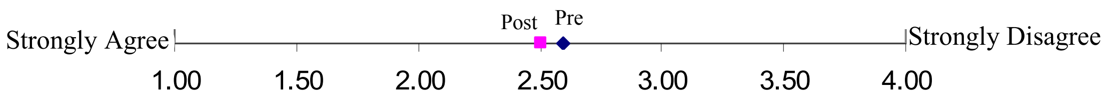
I am aware of career opportunities in engineering and technology



I have confidence in my ability to solve challenging problems



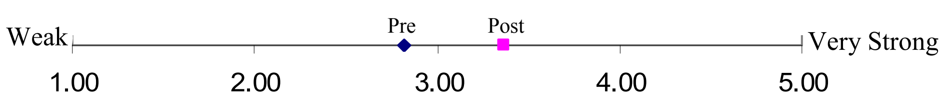
My math skills enable me to solve problems in engineering and technology



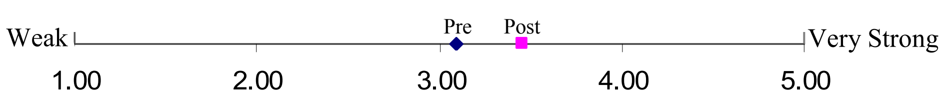
Students expressed a significant increase in there awareness of career opportunities in engineering and technology. However, only slight increases were seen in their confidence in their ability to solve challenging problems and in the usefulness of their math skills. One explanation for the small change in student confidence in math skills and ability to solve challenging problems could be that module use resulted in a healthy reassessment of student understanding. One teacher has commented that the module made students think differently and apply what they have learned, perhaps causing students to realize that problems are not always straight forward and that they do not usually have one simple answer. In the future, focus groups will be held to further investigate this hypothesis.

Students were also asked to indicate their current level of understanding of a number of engineering design and hemodialysis topics. The scale for these12 statements was from 1 to 5 with 5 indicating very strong, 3 indicating moderate and 1 indicating weak. Mean student responses showed a large improvement for many of the statements in this category. Examples are shown below.

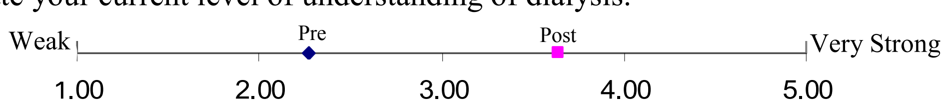
My ability to list the steps in the engineering design and development process is:



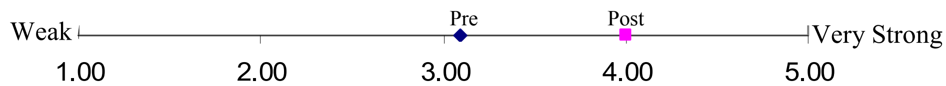
My understanding of what is meant by design constraints is:



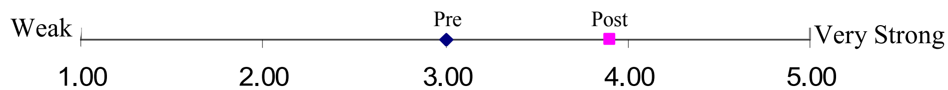
Please rate your current level of understanding of dialysis.



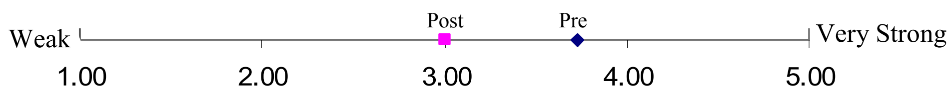
Please rate your current level of understanding of diffusion.



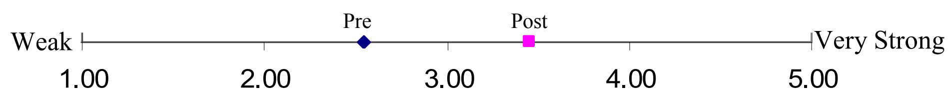
Please rate your current level of understanding the relationship between diffusion, concentration gradient and temperature.



Please rate your current level of understanding of co-current or counter-current flow.



My understanding of mathematical simulation is:



The increase in student confidence with scientific terminology related to dialysis is consistent with their increase in assessment scores in this area. Furthermore, the students' increased ability to list the steps in engineering design and development process as indicated in their content assessment scores was supported by their response to the interest and attitude question pertaining to that topic. Surprisingly, students showed a notable decrease in confidence level related to their understanding of mathematical simulations. The authors speculate that this decrease may reflect a new appreciation for the complexity of engineering design and a healthy reassessment of their expertise after exposure to the curriculum unit. Similar decreases in confidence in math have been reported in the literature.[5] Close attention will be paid to whether this trend persists in future trials and modification will be made to the module as necessary to address this issue.

Finally, students also took a Post Module Questionnaire at the completion of the curriculum unit. This questionnaire was broken into two sections. The first section asked students to indicate whether their interest or skills in certain areas increased, decreased or remained the same as compared to before using the module. Results are shown in Table 1 and are presented as the percent of students indicating each response.

Table 1: Student responses to Part 1 of Post Module Questionnaire

Statement	% Increased	% Decreased	%Same
My interest in pursing a career in engineering or technology has:	18.2%	13.6%	68.2%
My ability to work on teams has:	18.2%	18.2%	63.6%
My confidence in successfully studying engineering or technology has:	27.3%	18.2%	54.5%
My understanding of how math helps solve problems in engineering or technology has:	18.2%	4.5%	77.3%
My knowledge of engineering or technology fields has:	54.5%	4.5%	40.9%

My understanding of design constraints has:	36.4%	4.5%	59.1%
My understanding of mathematical simulation has:	27.3%	4.5%	68.2%
My understanding of the engineering design process has:	36.4%	9.1%	54.5%
My confidence in my engineering or technology skills has:	27.3%	9.1%	63.6%
My understanding of career opportunities in engineering or technology has:	27.3%	4.5%	68.2%

Over 50% of students reported an increase in their knowledge of engineering or technology fields as a result of using the curriculum module. In addition, over 35% of students report an increase in understanding of design constraints and the engineering design process. The module also appears effective in increasing understanding of career opportunities, mathematical simulation and how math helps solve problems in society, with more than three times the number of students reporting an increase as those reporting a decrease for these categories. When aligned with data from the Interest and Attitude Questionnaire, it is interesting to note that students report an increased understanding of mathematical simulation, but decreased confidence related to the topic. However, confidence in overall engineering and technology skills showed a significant increase.

The Post Module Questionnaire also includes a second section in which students are asked to agree or disagree with statements regarding the effectiveness of various aspects of the module. Student responses to these questions are listed in Table 2.

Table 2: Student responses to Part 2 of Post Module Questionnaire

Statement	%Agree	%Disagree	%Neutral
This inquiry-based learning engineering module has been academically challenging.	36.4%	18.2%	45.5%
The use of interactive animations (where you could move slide bars to change temperature, concentration, and molecular size) enhanced my learning.	63.6%	4.5%	31.8%
The mathematical simulation gave my team ideas of how to start the design challenge project.	22.7%	18.2%	59.1%
The final team design project has been challenging.	42.9%	9.5%	47.6%
The quality of our final project was enhanced by the team approach.	50.0%	22.7%	27.3%
The team experience helped me learn.	31.8%	18.2%	50.0%
The hands on demonstrations were useful in understanding the concepts.	40.9%	18.2%	40.9%
I understand the connection between the pre and post mini-design activities (Separate This! and In Search of Snap Krackle and Pop!) and the overall design project.	63.6%	4.5%	31.8%

This section of the Post Module Questionnaire indicates that the majority of students believe that interactive animations enhanced their learning, and that the quality of their final design project was enhanced by the team approach. The majority of students also understood the connection between the pre and post mini design activities and the overall design project demonstrating the effectiveness of including these activities. Nearly half of the students agreed that the final team design project was challenging and that the hands-on demonstrations aided understanding of concepts. These results indicate that the portions of our module that keep the students actively engaged aid in their learning and understanding of the material presented.

When asked what improvements could be made to the module, the most common student response was that the online materials were slow and that the technology should be improved. Indeed, issues have arisen due to differing computer infrastructure and networking in school systems, which at times has caused the online materials to run slowly. We are currently working with schools that are testing the module to improve their networking capabilities to remedy this problem.

Results: Professional Development Workshop

During the summer of 2005 a two day Professional Development Workshop was initiated for school teachers interested in implementing the module during the 2005/2006 academic year. Eight technology education teachers attended the training. The educators were "taught" the curriculum in the same order and format that they would use with their students. They took all the assessments, watched the professionally produced video segments, navigated the online tutorial and simulation and participated in the pre and post-module mini-design activities. While the final design project was not implemented during the workshop due to time constraints, a lengthy discussion about the project was included. Expectations of how the module should be presented in the classroom were outlined including a detailed discussion of the purpose of each curriculum component. The goal of such rigorous training was to maximize the integrity of implementation from classroom to classroom such that data may be compared among trials in various schools.

At the conclusion of the training, the teachers were asked to complete a survey to evaluate strengths and weaknesses in the module as well as the workshop. The teachers' responses to the survey (see Table 3) were highly favorable and encouraging. Most of the teachers who attended are planning to incorporate the module in their classes during the 2006 spring semester.

Table 3: Teacher responses to Professional Development Workshop Survey.
Scale: 1=Strongly Agree to 4=Strongly disagree

Statement	Mean Response ± standard error
Determine usefulness of the following topics	
Opening video of patient	1.4 ± 0.2
Content tests	1.5 ± 0.2
Hands-on exercises	1.0 ± 0.0
Short engineering challenges	1.1 ± 0.1
Design challenge video with patient and doctor	1.4 ± 0.2
Engineering design challenge	1.0 ± 0.0
Computer module	1.3 ± 0.2
Tests of design knowledge	1.3 ± 0.2

Ending Video	1.4 ± 0.2
Providing individual feedback	1.0 ± 0.0
Please indicate your feelings about the following statements	
I feel the design specifications given are appropriate considering the education level of my students	1.3 ± 0.20
The module fosters an understanding of the connectivity between engineering, science, and math	1.3 ± 0.2
The use of the module will facilitate active learning among students	1.4 ± 0.2
I am enthusiastic about using the education materials in my classroom	1.1 ± 0.1
Using this material in the classroom would be a waste of time	3.8 ± 0.2
The workshop was interesting	1.0 ± 0.0
The instructors were knowledgeable about the material	1.0 ± 0.0
The workshop was well organized	1.0 ± 0.0
Questions and comments were well received	1.0 ± 0.0
I feel reasonably prepared to use the material in my class	1.1 ± 0.1
This workshop was worth my time	1.0 ± 0.0
This workshop was the appropriate length of time	1.0 ± 0.0

Results: Using the INSPIRES Curriculum in the Education of Secondary Science Teachers

18 graduate students in a secondary Science Methods course were exposed to the Engineering in Healthcare module. All students in the course were current secondary education science teachers. The course emphasizes planning, curriculum, instruction and accountability for all students as learners of science, especially groups of students who have been historically bypassed by science education. A major theme of the course was how to make science accessible, valuable, and enjoyable to young people. Thus, the use of the online module was a natural fit, since one goal of the curriculum is to enhance the interest of underrepresented groups in science and engineering. In particular, the Engineering in Healthcare module was used to compare and contrast with more traditional science classroom inquiry. The student responses were highly favorable. Many of the students agreed that this approach to learning could benefit women and minorities. One Caucasian female student stated, "This curriculum seems to be a method to combat the lack of awareness and involvement that students (particularly women and minorities) have in the engineering field." Another Caucasian female student boasted, "The usual demons that haunt women or minorities are absent—this module fits all sizes!" Students also commented on the effectiveness of the module to expose students to real life applications of science. One African-American female wrote, "If we can make the relationship between science and everyday life more explicit, it is possible that these students will embrace science and engineering. I think this module did a great job of doing that." A Caucasian female student wrote, "Engineering is the answer to my students' greatest question: When will we ever need to use this? A method like the [Healthcare Module] is perfect for exposing students to the myriad applications of science in the real world." In all, the teachers were excited about the development of these modules and felt their use in the classroom would be valuable.

Conclusions

The results of preliminary trials using the INSPIRES Curriculum: Engineering in Healthcare module are very promising. Early data indicate the curriculum is successful at targeting ITEA Standards 8, 9 and 11. Teacher response to the curriculum has been overly enthusiastic suggesting a need and desire for the materials being developed. The inquiry-based learning approach appears to be effective at teaching both scientific content and engineering design knowledge. The online interactive animations and hands-on activities, in particular, have been well received by students and a large percent indicate that these activities have aided their understanding of the material presented. Analysis is underway to evaluate whether the curriculum enhances student ability to apply the design process. Ongoing studies over the next two years will evaluate student learning in a much larger population and broader range of school systems.

The INSPIRES Curriculum will ultimately include five stand-alone modules with similar format. Development of Engineering in Flight and Engineering Energy Solutions is currently underway with classroom testing slated to begin in spring 2006 and fall 2006 respectively. Engineering in Communications and Information Technology and Engineering and the Environment will be developed over the next year.

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