Integration of Medicine and Robotics – an online teacher professional development program for STEM education

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Abstract

The goal of this project is to create and implement a web-based professional development program that teachers can access and, as a result of the training, are able to implement, in their classroom. This program is an extension of a previously developed face-to-face program, in which robotics and information technology are applied to solve biomedical problems. The program was designed to enhance student knowledge in biology, medicine, physics, mathematics, engineering, and information technology, and become part of a standard STEM course curriculum. As a result of the original program, face to face workshops for sixty in-state middle and high school teachers were held, and it is estimated that over 3,000 students have been exposed to the concepts of robotic surgery, the engineering design process, and enhanced learning through use of the original program. In addition, six teachers have developed courses within their schools based on the original program, and another teacher developed and taught a summer enrichment program for 8th grade students with the focus on the integration of medicine and robotics to enhance STEM education.

The current program seeks to expand the reach of the original program to teachers outside our immediate geographical area. This project was started in 2010 to create a web-based version of the original professional development program. The utilization of a web-based approach to this type of program allows the use of both asynchronous and synchronous delivery options that can accommodate the range of activities to be undertaken: readings of resource material, teacher contributions to discussion, as well as submission of assignments by teachers. This paper describes the process, as well as the assessments from the first cohort.

Index Terms – Pre-engineering Curricula, Robotics, Attitudes toward Science, Mathematics and Engineering, Knowledge about engineering careers.

Introduction

Over the next few years, the demand for engineers is expected to increase faster than for all other occupations combined but the number of students pursuing careers in engineering is not increasing adequately to meet this demand. In fact, the number of students completing baccalaureate degrees in engineering has increased very little over the last decade[1]. Increasing the presence of engineering in K-12 education, especially through the application of science and mathematics, has become a high priority[2]. Most secondary school students still do not have an adequate academic background in science and mathematics to study engineering and do not really know what engineers do. Most students are not exposed to engineering topics in their science and mathematics classes during their K-12 studies because teachers have not been trained to incorporate these topics into their curriculum and instruction[3, 4, 5]. As a result, too many students lack an interest in more advanced studies of science and mathematics and are not adequately prepared to enter STEM programs in college or pursue careers in STEM fields

Medibotics

To address this issue, the authors were awarded a National Science Foundation ITEST grant. During the original Medibotics NSF ITEST program, a total of 60 teachers participated in a series of school year and summer workshops, where they worked in teams to model four simulated surgeries using the LEGO® NXT Mindstorm kits. Training was face-to-face, and the assessment of teacher proficiency in terms of understanding the medical robotics program was demonstrated through a Capstone project. A workbook including details on construction of the robots, computer programming, the mathematical and scientific topics involved in each surgery, and other support materials for use in STEM classes was created.

The emphasis on biomedical engineering applications and robotics is especially important because many engineering applications tend not to be aligned with the interests of a significant portion of the student population, namely females. Fields such as medicine, dentistry, and law have seen significant increases in women entering their profession[6, 7] because women tend to be motivated by a desire to contribute to society. Engineering and the related scientific and mathematical tools are seldom seen as a means to enhance society. However, more students, particularly females, are beginning to recognize that biomedical engineering (defined as using traditional engineering principles to solve problems in biology and medicine) provides for an overall enhancement of health care, which of course is an effective way to help people and improve society[8].

The Medibotics pre-engineering curricula incorporates grade-appropriate prototypes of robotic surgeries into secondary school curricula providing students with hands-on experiences that simulate real-world problems to encourage their interest in engineering and information technology and provide information on careers in these fields[9]. Curriculum modules that are aligned with the New Jersey Core Curriculum Content Standards (NJCCCS) and national standards have been developed. Faculty and graduate students, along with the Center for Pre-College Program (CPCP) staff, worked with two cohorts of teachers from public and parochial schools in urban areas of North and Central New Jersey, to integrate the Medibotics curricula into 7th-12th grade science and mathematics lessons. Teachers were trained how to use Medibotics in their classrooms during an intensive two-week summer workshop and received additional training during a one-week workshop the following summer and several one-day workshops throughout the academic year.

From this grant, the authors found that the analyses of responses to the Teacher Concerns-Based Questionnaire[10] indicated that before beginning the Medibotics program, most teachers were concerned about implementing the new curricula, which is to be expected, but by the time they completed the program they were feeling more confident and eager to help their students. By the end of the school year, after classroom experience with the new curricula, the teachers had fewer concerns and were beginning to think about how they could collaborate with other teachers. Teachers' attitudes toward engineering, their knowledge of careers in engineering, and the information they had to help students interested in studying engineering increased as a result of participating in the Medibotics program. Students' attitudes toward engineering, their knowledge of careers in engineering, and their self-efficacy for engineering type skills increased significantly.

As information about the Medibotics program was disseminated through conference presentations, journal articles, book chapter[11-15] and teacher learning communities we received numerous requests, including many through LEGO Education, to deliver the curriculum materials developed through Medibotics to audiences outside the Northern and Central regions of New Jersey. While the Medibotics program was very successful in training local teachers, there are significant challenges in trying to duplicate the delivery of the professional development program in order to reach a larger audience of teachers. Distance learning programs for professional development of teachers can be very useful when face-to-face programs are impractical[10], but to be effective the quality of learning materials and availability of support is critical.

The VirtualMedibotics™ Professional Development Program

Subsequently, the investigators received a three-year, $300,000 grant from the ExxonMobil Foundation to convert a portion of the Medibotics training program and curriculum materials into an online (web-based) professional development system, entitled the VirtualMedibotics™ program. This program, including a self-assessment protocol of teacher proficiency, has been implemented with a first cohort of 20 local NJ secondary school teachers, who will complete their training by July, 2013. A second cohort of 40 teachers from the Northeast US will begin in late spring of 2013 and complete their training in July 2014.

A professional development program that moves from a face-to-face mode to distance learning mode faces further challenge from a pedagogical perspective. A common approach to distance learning is to provide training and support through a predefined course package. This approach however is not consistent with what are considered "best practices" of teacher professional development[17]. Any professional development program is most effective when it relates to the participants' professional activities. Teachers bring with them a diverse set of strategies for teaching and learning from their own professional experiences. A more interactive environment that provides teachers with opportunity for structured reflection and discussion with colleagues is needed. A support-led rather than by package-led form of distance learning is necessary. The VirtualMedibotics™ program has been designed to provide pre-defined web-based instruction with computer-mediated communication to support interactive participation and collaboration among teachers.

The Virtual Medibotics™ training program uses a web-based approach to distance learning that allows both asynchronous and synchronous delivery options to accommodate the wide range of activities necessary for completion. Teachers follow a series of web-based instructional modules containing videos, reading assignments, links to related websites, examples from the workbook, learning objects and self- assessment measures. Assessments were developed for each of the learning objects (videos), as well as a separate assessment of the learning outcome(s) related to that learning object. This allowed the investigators to follow the progress of each teacher. The material was uploaded to a course management system (Moodle) which gave the teachers the ability to post questions. The videos were a result of a complete workbook developed under the original Medibotics NSF grant.

There are two primary online resources for this program. The first is a general web site that is available to the general public. This public website has been created. The second online

resource is the online learning community that will be used by participating teachers. The material used for training consists of over 30 videos that focus on learning objects within the program, with assessments for both the learning outcome from the video, as well as an assessment on the video. This program will culminate with a capstone project, where the group of teachers will develop their own surgery. The online program consists of two cohorts training of teachers, with modification of the second cohort material based on the assessment and feedback from the first cohort teachers.

Discussion forums allow teachers to share content, ideas, instructional strategies, and alternative perspectives. There are nine modules in this program, and the first module present the basics elements necessary to construct a robot, programming procedures, and background information on the Medibotics program, engineering design process and the LEGO® Mindstorm NXT system. The second module shows the development and implementation of a mock Coronary Bypass surgery. Another module examines the elements of a dental crown surgery that reinforces the basics of programming and introduces the teachers to more advanced topics. A fourth module has the teachers modifying a surgery, without any additional assistance, to test their own knowledge as a lead-in to the Capstone Project. The Capstone Project[18] has been designed to be a shared, culminating learning experience for the teachers, providing for learning through a self-directed, integrated process that allows project staff to assess how well the teachers have understood their training and can apply the Medibotics curriculum. The VirtualMedibotics™ website has the ability for teachers to upload their capstone projects, which will also provide additional surgeries for future participants.

To achieve the professional development goals and objectives of this program, the project outcomes must increase and enhance teachers' applied skills and knowledge in science, technology, engineering, and mathematics (STEM). The professional development experience is designed to assess the performance outcomes of the overall mastery of the VirtualMedibotics™ teachers as a result of the project. With regard to the program outcomes, upon completion of the project, the teachers are able to:

1. **Identify** a real-world medical condition and **formulate** a mock surgical procedure related to the condition through the application of the engineering design process.
2. **Select** appropriate input/output (I/O) devices and LEGO components; **construct** a physical model; and **write a** software program that integrates the NXT brick for the computer-assisted surgery.
3. **Illustrate** the science, technology, and mathematics principles that are integrated into mock computer-assisted medical procedures and **select** the appropriate student performance indicators from the state content standards.
4. **Apply** an engineering design process to research, design, construct, computer program, and communicate robot designs for mock surgical procedures.
5. **Prepare** one or more lesson plans that integrate mock surgical procedures into the school/district curriculum, and **propose** instructional strategies or practices such that students develop their critical thinking, problem-solving, and content knowledge for real-world medical conditions by applying the engineering design process.
6. **Synthesize, compare, contrast** , and **evaluate** with peers in a Virtual Medibotics Learning Community for reflective dialogue on effective practices in lesson plan

development, instructional strategies, and authentic assessment of student learning before, during, and after Medibotics learning experiences

A series of three milestones have been identified over the course of this professional development system. The first milestone is the completion of the first surgery, which is demonstrated by teachers uploading a video of this surgery via Moodle. The second milestone is the completion of both a second surgery and a variation of a second surgery, where the variation is more open ended than the original two surgeries. The third milestone is the completion of a capstone surgery. In all three milestones, the assessment used to show that teachers have completed this milestone is a video of the completed surgery, uploaded to Moodle.

Twenty teachers began training through the VirtualMedibotics™ program in September, 2012 and will complete training by July, 2013. A second cohort of forty teachers is in the process of being recruiting, and 30 teachers have currently been accepted into this second cohort. The expected date of completing this training will be June, 2014.

There are several differences in the online version as compared to the original Medibotics program. The first difference is the period of time for training. In the original Medibotics program, the training was performed over a two year period, with school year and summer workshops which worked well for local schools local. The online version is to be completed within one year. The original Medibotics program included five surgeries including the capstone project, while the online version includes only three surgeries, including the capstone project and a variation of the second surgery. The purpose of the initial group was twofold:

1. Teachers will synthesize and apply the learning outcomes of the VirtualMedibotics™ system in their STEM classes or in after school programs.
2. Project staff will determine what elements of this program needed to be modified, prior to the start of the second cohort of teachers.

It is estimated that teachers should be able to complete the entire program in approximately 60 hours, spread over a 13 month time period. The ExxonMobil Foundation grant enables teachers to receive a small stipend for completing various milestones, a LEGO NXT Mindstorms kit, single license software and webcam, and professional development credits.

Preliminary Results

For the first cohort of teachers, two of the 20 original members have completed both Milestone 1 and Milestone 2, and are beginning their Capstone Project. Nine of the 20 teachers have at least 50% of the program complete and are at least 75% complete with respect to where we have estimated they should be based on a timeline developed by the authors. We are currently surveying teachers who are lagging behind, to identify changes that could be made to the program. For those first cohort members who have completed a significant portion of the program, what we have found is that they consistently upload on a weekly or bi-weekly basis. The teachers who sporadically participate, especially during Summer, 2012 or during a school break, are significantly behind the schedule.

This diversity of activity is not uncommon[19]. There have been over 30 comments on 17 of the videos, and the authors have implemented these changes before February, when the first members of the second cohort of teachers started. Samples of the comments are:

- Viewer should be told to build the base robot before watching the video so that they can test the program
- Discussion of decibels was premature. Video to accompany rotational motors could heighten understanding
- Medibotics Programming 101 Document (one of the modules) was helpful in completing the Assessment of Learning Objective
- Provide more examples of using the constructs to have the robot perform specific tasks
- Provide a copy of the slides in addition to the video

We have provided copies of slides used in the videos, and this has received very positive feedback. It has allowed teachers to print the slides being used in the video and use this print to make notes during the video.

By using both the Activity and Participation reports from Moodle, the authors were able to infer:

1. Teachers were still becoming acclimated to the program and therefore needed to review the material multiple times (as in the case of the first few introductory videos),
2. Information was presented in a way that was difficult for the teachers to grasp and therefore they needed multiple views to better understand the material (we can cross reference with the Learning Object Assessments to see if this was the case)
3. One teacher, who viewed learning objects multiple times, were using the video to show their students.

A preliminary review of the learning outcomes assessment shows that teachers are able to develop the necessary skills and knowledge from this web-based program. Most teachers have completed the assessments on their first submission, with only a few teachers requiring a resubmit due to lack of detail or minor flaws in the programming. The capstone project will be the final assessment, and that should be completed by July, 2013.

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