

AC 2010-156: A CAPSTONE APPROACH TO EXPLORING TEACHER OUTCOMES FROM PROFESSIONAL DEVELOPMENT

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A CAPSTONE APPROACH TO EXPLORING TEACHER OUTCOMES FROM PROFESSIONAL DEVELOPMENT

Professional Development

Professional development for teachers is considered a key vehicle for educational reform and the need for improving classroom instructional practice and student achievement¹. Professional development is integral to increasing teachers knowledge and skills, and to learning effective application of the skills in the classroom in order to meet the needs of all learners². Systematic studies of the necessary basic skills have been reported¹⁻⁸ but less is known about the process of acquiring these skills within the cause and effect relationships between teaching strategies and curriculum, learning outcomes, and within the context of professional development programs.

Some of the key factors identified for effective professional development include¹⁻⁸:

- Engaging teachers in practicing concrete tasks related to teaching, assessment, and observation of learning.
- Drawing upon teachers' questions, inquiry, and experiences.
- Including time for collaboration, sharing and exchange of ideas and practices.
- Building on teachers' current work with students, as well as new ideas.
- Providing modeling, coaching and problem-solving around specific areas of practice.

The planning of professional development programs that effectively employ these factors and lead to desired teaching practices is not a simple process and is still a subject for further research. According to Joyce and Showers⁹, "It has been well established that curriculum implementation is demanding of staff development - essentially, without strong staff development programs that are appropriately designed a very low level of implementation occurs." Too often, short term teacher training institutes and after school workshops are seen as ends in themselves. These "one shot" approaches to staff development may fail to result in lasting changes in teaching behavior because teachers are not provided with the opportunity to experience success. Schumm, Vaughn, Gordon, and Rothlein¹⁰ suggest that teachers are not likely to change their classroom instructional behavior unless they are given the skills, knowledge, and confidence to do so. In the past, staff development efforts have typically focused on isolated instructional behaviors such as cooperative learning, teaching to learning styles, or classroom management skills.

Professional development programs, needed to effect changes in several dimensions of teacher attitude, belief, and practice, will have to be long lasting and designed to include integration with classroom practice. Teachers who have depended heavily on textbooks need on-going support and continuing training to effect the desired behavioral changes. Heightened expectations are not likely to be met by the mere distribution of an attitude survey at the end of workshops. Teachers need the opportunity for structured reflection and discussion with colleagues on what constitutes good teaching practice. Teachers should be removed from the isolation of their classroom to work with colleagues on learning and teaching, and curriculum planning and implementation.

An alternative perspective on the features influencing effective professional development outcomes is provided by a CCSSO report⁸, in which five features were considered: three core features (active learning, coherence, content focus), and two structural features (duration, and collective participation) but not much is known about how these features of professional development relate to changes in teacher practice¹. 1) **Active Learning**: Teachers are involved in discussion, planning, and practice, 2) **Coherence**: Activities are built on what they are learning and lead to more advanced work, 3) **Content Focus**: Content is designed to improve and enhance teachers' knowledge and skills, 4) **Duration**: Professional development for teachers extend over a two-year period, and 5) **Collective Participation**: Teachers meet in discipline and grade level groups to discuss strategies and content, and to develop approaches that they present to their peers.

The goals for the implementation of teacher professional development programs should be to enhance teachers' skills and knowledge, improve their classroom practice(s) and increase student learning. How to accomplish these goals within the context of the existing curricula that are aligned with the skills and knowledge specified by state content standards is also a very important issue. Evaluation of professional development should include a combination of teacher application of acquired skills and knowledge and teacher reflection, as well as classroom observation, and ongoing assessment of student performance.

The current paper describes a long-term (two-year) professional development program along with efforts to further understand what an effective professional development program is. A capstone project was integrated into the program to help determine whether the desired skills and knowledge were acquired by the teachers and the resulting impact on their classroom practices.

The Medibotics Project

Medibotics, the Merging of Medicine, Robotics and Information Technology, is an intensive professional development training program designed to introduce students and teachers to engineering and information technology through the use of robotics¹¹. Because of its multidisciplinary nature, the study of robotics in the classroom can be a valuable tool for the practical, hands-on application of concepts across various engineering, science, and mathematics concepts¹², as well as to solve biomedical engineering problems. Medibotics incorporates grade-appropriate prototypes of robotic surgeries, using LEGO Mindstorms Robotics kits for Schools and NXT Software, into middle and high school science, math, and pre-engineering curricula¹¹.

Curriculum units that are aligned with the New Jersey Core Curriculum Content Standards (NJCCCS)¹³ and national standards have been developed. During the training period, teachers were introduced to the curriculum units and shown how to perform four different robotic surgeries for implementation in their classrooms. Robotic surgeries are presented as problems to be solved. The selected surgeries involving the robotic systems have elements of actual medical procedures. Each surgery entails a different set of tasks and sequence of actions, requiring the development of different procedures and programs using the Mindstorms for Schools components and Robolab software. In addition, the Internet can be used to investigate the various real-world surgical applications, as well as discover the new and exciting application of robotic surgery. The robotic surgeries have been selected to:

- Demonstrate various surgical procedures and physiological areas.
- Utilize various sensors, and relate their functions to scientific principles.
- Use common food or craft products that are easy to obtain and maintain, as well as inexpensive (avoiding meat products, nut products and the need for refrigeration).
- Enable students to understand basic programming concepts.

The Medibotics project was designed and implemented to include each of those five features of professional development contained in the CCSSO report⁸: active learning, coherence, content focus, duration, and collective participation and a capstone session which provided the teachers the opportunity to use their acquired skills and knowledge in a new application. Teachers attended an initial two week summer workshop and a one week summer workshop the following summer. Academic year follow-up included one day workshops and in-class support by university faculty, staff and graduate students to work with and mentor teachers during the implementation process in the classroom and program assessment. In addition, an electronic, peer-learning community was established, for communications among teachers and university personnel, and for online professional development activities.

Elements of the two-week summer workshop for the teachers included:

- Introduction to robotic technology.
- Discussion of the Lego system – hardware and software.
- Introduction to appropriate programming concepts.
- Discussion of design process and engineering design.
- Discussion of scientific principles utilized in construction and operation of the robot.
- Introduction to surgery and robotic surgery, including additional resources and websites.
- Description and demonstrations of surgery projects.

Peer-learning communities are intended to motivate teachers to learn continuously in the settings where they teach, apply skills and knowledge of improved curriculum practices, and stimulate job satisfaction through peer recognition of accomplishments in the classroom. Our peer learning community model was based on the best practices of professional development^{1,14}, including time for collaboration, sharing and exchange of ideas¹⁵. Moodle, which is being used to foster the online community, allows teachers from different school districts, and different schools within the same district, to discuss the robotic surgeries taught within the program. Teachers can draw on each other's experiences and support each other as they introduce the surgeries into their own classes. Moodle is also used to post general discussion questions and to obtain feedback from teachers that can be used to continuously improve the program.

The Capstone Experience

Traditionally, a capstone course is an opportunity for students to demonstrate that they have achieved the goals for learning established by their educational institution and major department¹⁶. The course is usually designed to assess learning and to do so in a student-centered and student-directed manner which requires the analysis and synthesis of knowledge and skills. The capstone should integrate those skills and knowledge acquired from previous learning experiences, as it requires the application of that learning to a project which can serve as

an instrument of evaluation. Thus, a capstone provides an opportunity to assess student learning not only in relation to content or skill specific areas but also within the context of applied expectations of the educational experience.

The capstone experience in the Medibotics project was designed to be a shared, culminating learning experience for the teachers, providing for learning through a self-directed, integrated, learning opportunity. The capstone required the teachers to integrate principles, theories, and methods learned throughout the program. Teachers needed to creatively analyze, synthesize, and evaluate learned knowledge in a project having a professional focus and communicate the results of the projects effectively at a professional entry level to their peers.

The advantages and characteristics of the capstone can be considered as a summary of the educative value of such an experience for teachers. The capstone experience:

- Allowed conclusions to be drawn from teacher performance regarding the level of knowledge acquired in the professional training. On going assessment during the experience allowed teachers to demonstrate that they learned what the project staff thought they had taught.
- Provided a summative opportunity to evaluate teacher learning at the end of the project.
- Was tailored to measure outcomes expected as a result of the professional development program.
- Placed expectations on the teachers by challenging them to become independent learners as the experience was learner-centered and self-directed.
- Required teachers to perform at higher level learning by forcing them to engage in analysis, synthesis and evaluation of past learning and apply it to new experiences.

This type of project can assess how well the teachers have understood the concepts from the other surgeries. In earlier workshops the teachers had been shown how to perform four different robotic surgeries, and have implemented them in the workshops. To assess how well the teachers have understood the concepts from the surgeries, teachers in teams of two, were assigned the task of creating a new surgery, using the robotic system, and then teach it to their peers. Creating a new surgery is modeled after a capstone course (or senior project) in the engineering and engineering technology disciplines. This could be a different surgery (or computer assisted procedure) involving the same physiological system as in the four previous surgeries, or it could a computer assisted procedure involve a new physiological system. Surgeries were presented to their peers, who provided feedback on each surgery, including suggestions for implementation in their own classrooms. Previously specified professional development learning objectives for teachers were applied to the teacher developed surgeries to assess their achievement of expected learning outcomes as a result of the training program.

In the creation of the surgery, teachers were asked to apply the engineering design process to create their own new surgery, which should showcase the synthesis of many topics covered during the almost two years of participation in the project. The process included:

Step 1 – Identify the Problem

Select a surgical procedure that has not been performed

Step 2 – Research the Problem

Gather information about the medical condition and surgical options

Step 3 – Analyze the Problem

The design constraints are:

- Use at least four sensors
- Use all three motors
- Use only one NXT brick

After the third step the teachers were asked to prepare a Research Brief:

- Description of medical condition and surgical procedure selected
- Statement of the learning objective for your Medibotics surgery
- Identify the NJ-CCCS and indicator aligned to the surgery (e.g. 1-2 indicators)
- Sentence identifying curriculum integration

After completing the Research Brief, they were to submit it to Moodle.

Step 4 – Brainstorm Alternative Design Solutions

Think of all the possible ways you can design the Medibotics Capstone Surgery

Step 5 – Model the “Best” Solution

Develop an Outline of Capstone Surgery:

- Identify math & science concepts that integrate into surgery
- Description of medical condition and surgical procedure selected
- List featured sensors and their function in the surgery
- Create a block diagram or flow chart, e.g. algorithm of the LEGO® robot’s motion to perform the surgery

After step 5, teachers were asked to submit an Outline of the Capstone Surgery on Moodle.

At their school, the teachers continued with:

Step 5 – Model the “Best” Solution *continued*

Design a physical LEGO robot and write software program

Step 6 – Test and Evaluate Model/Prototype

Step 7 – Refine and Retest Model/Prototype

Step 8 – Communicate Final Design

At the second summer workshop, the teachers completed and refined their surgery, presented an oral overview of their Capstone Surgery, and submitted it to Moodle at the end of the workshop. The oral presentations were meant to involve all participants, those presenting their new surgeries and the audience of the other teachers. The later were assigned the task of critiquing the new surgery, and to consider how each new surgery might fit into their curriculum and instruction, or how the new surgery might be modified for their own use.

The academic year one-day workshop that followed the Capstone experience was designed to continue the review of selected surgeries created as part of the Capstone. Six of the new surgeries were selected for this activity. The primary criterion for selection was to have surgeries that could fit into instruction in the several different science areas, mathematics, and

technology. Teams of 3-4 teachers were formed based on subject area they teach: Physics, Biology, Mathematics, and Technology.

At the workshop each team was given copies of each of the six surgeries, and assigned the task of engaging in a “Reflective Dialogue”¹⁷ for at least two of the six surgeries. The teams were to identify the key concepts and discuss whether selected surgeries would fit in their instruction and curriculum, how it would fit, and if it didn’t fit how they would modify the surgery. The teams spent some time with each selected surgery, and then presented their findings to all the teachers. Finally, they were asked to write up their findings and submit them to Moodle. The Reflective Dialogue was guided by the following questions:

1. Explain how you would utilize the surgeries in your curriculum. What concepts would be relevant to the surgeries? Why?
2. How would you expand the surgeries to enhance the concepts or allow incorporation of new concepts into the curriculum?
3. For each of the concepts, what skills and/or knowledge should the students be able to acquire? How would you assess the students’ acquisition of these skills and/or knowledge?

The Capstone as Assessment of the Medibotics Program

A key outcome of professional development programs is increased and enhanced teacher skills and knowledge, and how the outcomes fits within the context of the existing curricula that are aligned with the skills and knowledge specified by standards. Evaluation of professional development should include a combination of teacher application of acquired skills and knowledge and teacher reflection, as well as classroom observation, and ongoing assessment of student performance. The capstone project was an opportunity for teachers to demonstrate that they can apply the acquired skills and knowledge from the training program and serve as an instrument for the assessment of teacher outcomes that resulted from the professional development program. Accordingly, teachers in the Medibotics program were expected to be able to demonstrate the following performance objectives:

- (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.

The capstone task was to create a new surgery, using the robotic system, and teach it to their peers. The teachers were asked to develop, as a team of two people, a new surgery. This could be a different surgery (or computer assisted procedure) involving the same physiological system as in the four previous surgeries, or it could a computer assisted procedure involve a new physiological system. Surgeries were presented to their peers, who provided feedback on each surgery, including suggestions for implementation in their own classrooms. Fourteen teams of teachers were formed to develop Capstone surgeries, but only 12 teams actually presented their mock surgical procedure to their peers. The surgery presentations were reviewed from the perspective of the above performance objectives, which the teachers were expected to achieve through participation in the professional development program.

From examination of the Capstone projects with respect to objective 1, the Medibotics project staff determined that all of the teams of teachers were able to **identify** a real-world medical condition and **formulate** a mock surgical procedure related to the condition through the implicit application of the engineering design process. The teachers were able to clearly describe their formulated mock surgical procedure in terms of the robot movements. However, the explicit application of the engineering design process for the actual robot to perform the mock procedure was not described, e.g. no evidence of the engineering design process of the physical design in the formulated mock surgical procedure. The capstone project entitled, “Drilling a Carious Lesion in Preparation for a Restoration”, was developed by a team of teachers for the real-world medical condition of tooth decay. The procedure entails the robot identifying dental caries, e.g. areas of tooth decay, and “drilling” the decayed area of a tooth model. A light sensor (input device) is used to detect the “decayed” area on the tooth model, a motor (output device) with an internal rotation sensor (input device) is used to create and control the motion produced by the motor for the alignment and drilling process.

From examination of the Capstone projects with respect to objective 2, it was determined that all of the teams of teachers were able to **select** appropriate input/output (I/O) devices and LEGO components, with the exception that only one team mentioned that the servo-motor has an internal output device, e.g. rotation sensor internal to the motor, and one team incorporated the lamp component but did not identify the component as an output device. All of the teams were able to **construct** a physical model – with emphasis on the end product of the construction, e.g. the robot with no description of the processes used to construct a physical model, e.g. the robot itself. Due to time constraints for the development of the capstone project, the teams were in different stages of completing the task to **write a** software program that integrates the NXT brick for the computer-assisted surgery. However, many of the teams were able to demonstrate some aspect of the robot design and related programming to achieve a portion of the mock surgical procedure. Only 1 team embedded programming into their capstone project submission. Evidence of written software programs composed by the teachers was observed while floating around the room. However, no partial or complete software programs were submitted except from one team who embedded programming into the overall capstone project description. The capstone project entitled, “Cataracts”, was developed by another team of teachers that incorporates the selection of several input/output (I/O) devices, e.g. ultrasonic sensor (input device), light sensor (input device), and two compound servo-motor (output device) each with an internal rotation sensor (input device), with a variety of LEGO® components. Each of the I/O devices were appropriately selected to provide specific information to the microprocessor via

input devices and from the microprocessor via output devices for the robot's functionality. The ultrasonic sensor is used to detect the location of the two eye models - one model has a healthy lens and the other model has a "cataract"(cloudy) lens. The light sensor is used "to differentiate between opacity and clarity of the lens" on the eye model. The first servo-motor with an internal rotation sensor is used to provide the energy for the motion of the wheels that enables the robot to approach the eye models under the detection of the ultrasonic sensor mounted on the front plane of the robot. The second servo-motor with its own internal rotation sensor is used to create and control the motion of a compound gear system for a "robotic arm" that houses and positions the light sensor component for detecting the healthy versus diseased lens.

From examination of the Capstone projects with respect to objective 3, it was found that all but one team of teachers were able to correctly **illustrate** the science, technology, and mathematics principles with various degrees of success, but only 8 of the 12 teams were able to **select** appropriate performance indicators from the standards, and even they had various degrees of success in the selection of appropriate indicators.. The later is critical in terms of aligning classroom lessons with state content standards, and it has been our experience that this is a difficult task for teachers to accomplish¹⁸. For math topics, the capstone project, "Urine Analysis Assay has for illustration of math topics, "Zip, Nada, Zero, No math". The capstone project entitled, "Drilling a Carious Lesion" provides clear, well-stated learning objectives linked to the performance indicators of the content standards, related to the science, technology and IT, but not in mathematics. The project then tried to relate the learning objectives to the performance indicators, and also listed performance indicators in mathematics, which were appropriate for the surgery, but was not explicitly stated in the associated learning objectives. In addition, instead of providing assessment strategies for each performance indicator, the primary assessment instruments were "written and/or verbal review of the basic tooth anatomy and physiology using established assessment techniques (quizzes, tests, etc.). All the capstone surgeries included that type of assessment statement(s).

From examination of the Capstone projects with respect to objective 4, it was determined that all of the team of teachers were able to implicitly **apply** an engineering design process to research, design, construct, computer program, and communicate robot designs for mock surgical procedures. However, the project expectation through the five objectives was to explicitly apply some iterative process of engineering design as evident in continuous documentation such as class note, in-class logbook, or other expressive means of documented communications which required daily/on-going documentation. In general, the descriptions of the capstone mock surgical procedures emphasized the process and product of the programming, but only the product of an array of actual design ideas, decision making processes used to select one design for the construction of the robot. Only a couple of teams mentioned the process of keeping a journal with no explicit information integrated either in the instructional or assessment methods. The capstone project entitled, "Lung Biopsy", was developed by a teacher that implicitly incorporates the application of the engineering design processes for both the robot and computer programming. The learning experience for the acquisition of skills and knowledge is the strategies of direct instruction for content background of the medical condition; and inquiry-based learning for the exploration, design, assembly, and creation of an original robot and computer program to remove a small piece of unhealthy lung tissue, e.g. blue sponge, among healthy tissue, e.g. pink sponge. To demonstrate the acquisition of skills and knowledge, the description of the surgical procedure states "Students will keep an Engineer's Journal. This

journal will be updated daily with the following criteria: Description of design, discussion of problem, sketches of the robot, and steps to the programming."

Since the Capstone did not require the preparation of lessons plans, that component of objective 5 could not be assessed from this activity. However, each team was asked to provide instructional strategies that would be used for students to acquire expected skills and knowledge. All teams were able to provide instructional strategies which included direct instruction, using lecture and power point, and exploratory activities by the students in the construction and programming of their robots. It is interesting to note that only 5 of the 12 surgeries contained explicitly instruction in the process of engineering design, while all surgeries included instruction on the programming of the robots.

At the end of the Capstone, the teachers were asked to what extent they believe they met the performance outcomes, by responding to the following questions:

1. To what extent did the Capstones experience provide you with the ability to **identify** a real-world medical condition and **design** your own surgical procedure related to the condition?
2. To what extent are you able to **select** appropriate input/output (I/O) devices and LEGO components to construct a physical model for the condition you identified? Could you write a software program that integrates the NXT brick for the computer-assisted surgery?
3. To what extent did the Capstones experience provide you with the ability to **apply** the Engineering Design Process in researching, designing and constructing a robot for the surgical procedure you identified?
4. To what extent did the Capstones experience provide you with the ability to **illustrate** the science, technology, and mathematics principles that were integrated into the computer-assisted surgery?
5. To what extent did the Capstones experience provide you with the ability to **select** the appropriate student performance indicator(s) from the corresponding state (and national) content standards?
6. To what extent did the Capstones experience provide you with the ability to **prepare** one or more lesson plans and **propose** a strategy to integrate the lesson(s) into the school/district curriculum such that students have the opportunity to develop their own solution to the selected real-world medical condition?

The responses of the teachers reflect their beliefs that they did achieve the performance outcomes expected of them as a result of the professional development program, and that the Capstone experience reinforced for them the skills and knowledge they had acquired as a result of the Medibotics program. Comments included:

"It was a real challenging experience."

"It helped to remove my concerns about the ability to implement these concepts to students.."

"This was a very effective experience to achieve these goals. Making up your own activity requires real 'thinking' and understanding."

"'Capstone' was a valuable learning experience, and fun too!!"

"It definitely allowed me the opportunity to identify a real-world medical condition and to design my own surgical procedure."

“I was able to reach into my own creativity and use skills not accessed in years.”

“It was a great experience. You provided a model for creating the surgery that transferred will to writing curriculum & lessons for the students.”

”I had a great time experimenting with design, construction, and research.”

“The Capstone was a furthering of the knowledge we already had.”

“Understanding the math and science provided a pivotal role in completing the surgery. Once understood, it could be taught and implemented.”

“I have been able to successfully prepare lessons and execute them.”

Conclusions

The capstone experience in the Medibotics project fulfilled its goal as a culminating learning experience for the teachers, as it required the teachers to integrate principles, theories, and methods learned in prior workshops provided during the program. As a summative tool, it provided the opportunity to evaluate teacher learning at the end of the project, as it allowed program staff to draw conclusions from teacher performance regarding the level of knowledge acquired in the professional training. The teachers rose to the challenge to become independent learners, and perform at higher level learning by forcing them to engage in analysis, synthesis and evaluation of past learning and apply it to new experiences. For the most part, the teachers were able to demonstrate that they could apply the acquired skills and knowledge from the training program and serve as an instrument for the assessment of teacher outcomes that resulted from the professional development program.

The assessment of the Capstone projects showed two areas of concern where the extent of acquisition of skills and knowledge by teachers did not appear to be at the level expected by project staff. Approaches used for these two areas in the professional development activities will be revisited and modified, as necessary, for future professional development programs.

1) Only two-thirds of the teams were able to select appropriate performance indicators from the standards. This is a critical issue for alignment of the instruction with state content standards, and is an important skill for all teachers to acquire.

2) Many of the teachers did not seem able, or chose not to explicitly demonstrate the appropriate use of the engineering design process in the mock surgery, and the primary focus of the teachers appeared to be only on the product, and not on the process to optimize the operation of the robot. This was also seen in their proposed classroom instructional strategies, where about 40% of the surgeries made the attempt to explicitly include the engineering design process and example applications in the instructional strategies to be used with their students.

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