Engineering-Based Learning as a Pedagogical Approach for Teaching STEM Classes

ABSTRACT

Josiah Quincy Upper School (JQUS), a Boston Public School located in the Chinatown and Bay Village neighborhoods, serves a socioeconomically and ethnically diverse population of students in grades 6-12. JQUS is the first Boston-area International Baccalaureate (IB) public school; through IB it aims to develop its students to be knowledgeable and productive members of a global society through an education that promotes cultural awareness, skillful use of information, and personal renewal along with both individual and community path-finding for the 21st century. The varied challenges of the 21st century society and workforce necessitate the adaptation of pedagogy and content that better engages our students and prepares them for real-world success.

Teaching STEM (science, technology, engineering, mathematics) concepts has always been recognized as a worthwhile endeavor, but finding efficient ways for K-12 teachers to effectively convey these concepts and for students to retain their knowledge has been a challenge. To meet this need, Northeastern University's NSF-funded CAPSULE program was developed as a professional development program that guides STEM teachers to learn how to use and implement engineering-based learning (EBL) in high school classes. Content included are the engineering design process, CAD modeling, capstone projects, and action plans for the academic year. Two JQUS teachers (math and technology) attended the summer 2010 CAPSULE program and implemented action plans during the 2010-2011 school year.

This paper covers the details of the JQUS math and technology CAPSULE curriculum and implementation of the action plans. It discusses the results of the lessons and projects, including successes as well as failures. Based on our results, we discuss lessons learned and provide recommendations for teachers looking to implement EBL in their classrooms and in various disciplines.

1 Introduction

Past educational models like T^4E focus on principles such as structured, effective, and efficient teaching models that encourage and engage hands on learning. Understanding past models like T^4E allows us to understand and improve upon how teachers learn and how that knowledge is transferred to students [1]. For most high school teachers, their teaching pedagogy depends on known working models, learning from colleagues, and attending professional developments based on new methodologies. For most educational professionals, they are familiar with traditional project-based learning (PBL) which centers learning around projects lacking a true structure and methodology [2]. Unlike project-based learning, our methodology is a new, improved upon process using assets of well-known PBL. In redesigning and improving professional development, the primary objective was to bridge the gap between science, technology, engineering, and mathematics (STEM) principles and real-world applications. Recently, there has been a paradigm shift in how students learn and absorb knowledge. Unfortunately, traditional lecture-based classrooms appear to be losing their effectiveness with students and there needs to be modified methods of teaching students.

CAPSULE was created to bridge this gap, to teach teachers a more structured method of implementing related projects into their curriculum. Unlike traditional PBL, our methodology incorporates and provides tools and a structured process to provide teachers with techniques of relating STEM theory to real world application. Engineering-based learning (EBL) uses well-established tools such as the capstone experience, the engineering design process (EDP), and Solidworks™ to engage and excite students in learning about STEM concepts. The uniqueness of EBL lies in the combination of the tool and methodology to provide teachers with a process where students can have control over the innovation they create. EBL gives a new way to think about problem solving, using not only a textbook, but also a more hands-on methods incorporating technology and process structure.

For any professional development, the measure of success is the participants' thoughts and takeaways from the course and also the impact on their students. If student education is not improved or there are no improvements in academic performance, the success of the program could be in question. Fortunately, both student and teacher implementation feedback has been tremendously positive. Although, some teachers discovered more challenges in the classroom than others, most teachers managed to implement some aspects of the CAPSULE program into their teaching pedagogy.

This purpose of this paper is to contribute to our understanding of the successes and challenges that teachers face during and after implementation of their CAPSULE action plans. We share our experiences of implementing CAPSULE in two of our courses. We also share the feedback and evaluation of our students to the CAPSULE experience.

2 CAPSULE Professional Development

CAPSULE is a two-week professional development program that was created in response to NSF's national effort to increase STEM enrollment after K-12 education. CAPSULE or CAPstone Unique Learning Experience is an intensive workshop experience that teaches STEM high school teachers about Engineering-Based Learning and provides tools for them to use in their classroom. Because each teacher has unique needs, the purpose of CAPSULE is to show that EBL has universal STEM applicability and can be modified for any STEM subject [3, 4].

During the two-week period, teachers learn how to implement capstone experiences for high school students through activities such as building a three-legged chair, using Solidworks to design an open-ended problem, and familiarize them with the capstone experience including presentation and poster session. Further, CAPSULE teachers learn from industry experts and how EBL and EDP are used in various industries. In addition to learning from outside experts and the CAPSULE team, teachers are able to converse and collaborate with colleagues to brainstorm, develop and compare lesson plans. For many teachers, the experience was beneficial for the connection to other technology/engineering-minded teachers, the resulting implementation plans, and the relevancy of professional development. Each teacher developed an action plan to implement in their course when they go back to their schools in the following school year. In addition to the two-week workshop, teachers were required to attend two callback sessions to share experiences, both successes and challenges that they had faced during implementation.

3 Purpose

Our purpose in this study is to examine the impact of the CAPSULE PD within the confines of STEM high school classrooms. Specifically, this paper addresses the following research questions: 1) What is the influence of the CAPSULE PD methodology in various STEM classrooms?; 2) What are the students' and teachers' perception of engineering-based learning, engineering design process, and capstone projects?; 3) How has the CAPSULE methodology changed the perception of STEM careers according to students?

4 Background

Josiah Quincy Upper School (JQUS) was recently authorized to be an International Baccalaureate (IB) Diplomma Programme school and has started to adjust curriculum accordingly for 11^{th} and 12^{th} grade [5]. IB mathematics includes four levels: Mathematical Studies Standard Level, Mathematics SL, Mathematics Higher Level, and Further Mathematics Standard Level. JQUS offers Mathematical Studies Standard Level and plans to offer Mathematics SL and Higher Level in the future.

Mathematical Studies includes eight topics: number and algebra, sets, logic and probability, functions, geometry and trigonometry, statistics, introductory differential calculus, and financial mathematics. Students take two types of assessments for the diploma: external assessment consisting of short-answer and open-response questions; and an internal assessment involving the collection of information or the generation of measurements, and the analysis and evaluation of the information or measurements.

Both assessments focus on core skills:

- Reading, interpreting and solving a given problem
- Using appropriate mathematical terms
- Organizing and presenting information and data in tabular, graphical and/or diagrammatic forms
- Knowing and using appropriate notation and terminology
- Formulating a mathematical argument and communicate it clearly
- Selecting and using appropriate mathematical strategies and techniques
- Demonstrating an understanding of both the significance and the reasonableness of results

- Recognizing patterns and structures in a variety of situations, and make generalizations
- Recognizing and demonstrating an understanding of the practical applications of mathematics
- Using appropriate technological devices as mathematical tools
- Demonstrating an understanding of and the appropriate use of mathematical modeling breadth and depth of study.

As a result of JQUS' acceptance as an IB school, math teachers felt the need to incorporate projects that teach these skills, emphasizing critical thinking and international-mindedness in keeping with the IB learner profile and Common Core standards [5-7]. Adjusting to a new curriculum while meeting district and state requirements, the adherence of all standards poses considerable challenges to JQUS for teaching project-based learning, writing, mathematical content and technology content. EBL via the CAPSULE program was chosen as an approach for transitioning the school's STEM curriculum into the IB Diploma Programme.

With every teacher limited by physical and monetary resources, many teachers have become very creative at utilizing local free resources. For mathematics at JQUS, one teacher leveraged many resources during the school year such as: Tufts Center for Engineering Education and Outreach (CEEO), Museum of Science Educator Resource Center, Northeastern University Center for Stem Education, and the EXCL Recycle Center.

5 Execution of Implementation Plan

Two teachers attended from JQUS attended the CAPSULE program, a mathematics teacher and a technology teacher. The benefit of having multiple teachers from a single school allows EBL and the CAPSULE methodology to build capacity within schools and within districts. We present the experience of each teacher in this section.

5.1 Mathematics Implementation

The original and implemented action plans for math differed greatly, mainly because of an unexpected change in teaching assignment from Geometry to Precalculus (see Table 1). For geometry, the goal was to have them experience the three-legged chair design and Habitat for Geometry.

The three-legged chair was suppose to take place in the first week of school, to: 1) introduce students to the engineering design process, 2) engage them in problem solving, 3) and give them ownership of their own learning. The chair design was intended to provide a meaningful context for the building blocks of geometry and help students see that math is not just an isolated set of rules to apply to homework problems. Assessments for this project were to be a reflection essay on student experience with the engineering design process, the physical prototype of the chair, scale drawings of the chair, and a Google SketchUp™ model of the chair.

Habitat for Geometry extended the math teacher group's original idea for house design to include service learning and the Boston community. Through volunteer work and donations, Habitat for Humanity Greater Boston builds and rehabilitates simple, decent houses for low-income families. Students were to design a Habitat for Humanity Greater Boston house for a lot in Roxbury, considering maximizing the size of the house itself, making the best use of space inside the house, and estimating costs. This project was to be implemented after the MCAS in late May 2011 as a way to pull together student learning for a culminating project. Students were to work in groups over a period of four weeks to complete the project, taking different leadership roles over the course of the project. The project was to include designing the footprint of the house to fit on a given lot while meeting City of Boston zoning restrictions, designing the floor plan of the house to fit inside the footprint while meeting Habitat for Humanity restrictions, answering real-life "builder" problems, and building a 3D model of the house in Google Sketchup.

Unfortunately, due to the change is subject assignment, the projects were not implemented as planned. However, two major projects aligned with International Baccalaurate standards replaced the three-legged chair project. The Habitat for Geometry project was also modified and partially implemented during the Perimeter, Area and Volume unit for Precalculus. New short-term projects aligned with International Baccalaureate standards were also created.

Table 1: Implementation Plan from CAPSULE PD

Proposed Action Plan	Actual Implementation
Major Projects 1) Three-Legged Chair 2) Habitat for Geometry **Short-Term Projects** aligned with Massachusetts state standards	**Major Projects** 1) Habitat for Precalculus (partially implemented) 2) Probability Carnival 3) SAM Animation **Short-Term Projects** 1) Paper Tower 2) Fish and Chips vs. the Fist of Doom

5.1.1 Habitat for Precalculus

The Habitat for Geometry project was modified to fit in a shorter time frame for the Precalculus class. Students were introduced to the project with a "design your dream house" activity in which they applied concepts of perimeter and area. Lack of readily zoning restrictions caused the project to be simplified to designing a two-story house for a four-person family, including: a master bedroom for the parents, two bedrooms for the siblings, a living room, a dining room, a kitchen, two closets on the 2nd floor, at least 3 bathrooms (on 1st or 2nd floor), a garage, and a fence that surrounds part or all of the house. The Google Sketchup™ portion of the project was not implemented. Students created floor plans for each floor, a landscape design for the house, yard, and fence, and completed a housing plan proposal. The proposal included calculations for area and perimeter and interior design according to the following questions:

A. List four options for kitchen flooring. How much will each cost? What do you need to install each? Choose one and calculate the cost to install.
B. List four options for painting the living room. How much will each cost? Choose one and calculate the cost to paint the living room.
C. You wish to add a rug to the living room. List the shape and size (area) of the rug you choose. How much floor space is left after you add the rug?

D. You want to add carpet to every room on the 2nd floor. How much will this cost? Find a specific type of carpet based on your preferences and show your work.
E. You wish to add a circular table into your dining room. Its diameter is ¼ the width of the room. Find the new area of floor space that is left once the table is placed.
F. You have $200,000 for upgrades. What will you spend it on? Where will you put it? Research anything appropriate that you would like to add to your home and list it along with the price, size, and anything else important about the item. Make sure it will fit!
G. About how much do you think the house you created is worth? What factors go into your assessment? Be as in-depth as possible!

5.1.2 Probability Carnival

The second major project was a four-day probability carnival in which students designed and built their own carnival games using classroom materials to apply probability concepts (theoretical probability, experimental probability, and expected value). The goal of the games was to maximize the profit made from consumers, which also draws on psychology and strategy. For example, the groups had to design their games to attract customers, but make the games difficult enough so that the expected values resulted in profit. The carnival included debate activities to reinforce analysis, student engagement, and structured argument skills. The design process included table debates to help them work out the kinks in their game designs and provide better products. Each group was paired with another group to give one opening statement and one rebuttal about the proposed game designs. Each group also conferred with the teacher about their game designs.

The groups took their feedback to create their games before the next class. Throwing/skill games were not allowed because of difficulty in calculating theoretical probability and playing the game 50 times to collect data. Many groups used dice or playing cards (e.g., Guess My Card or blackjack). One group made a fishing game out of materials they found in the classroom (see Figure 1). Their fishing pole was made from green scrap paper, blue ribbon and magnets. Their fish were made from construction paper and paperclips). They stayed after school to craft their game, even decorating each fish to resemble a member of the class. Another group made a Wheel of Misfortune out of a cardboard box, bulletin board paper, a pencil and half a pool noodle. Another created a homemade Deal or No Deal with shoeboxes instead of briefcases and a ringtone on her laptop for calling the “banker.” The students held a carnival day to see whose game made the most pretend money. Both sections attended and played each other’s games. After the carnival, guest judges formed a carnival committee that ultimately decided the best game after all groups advocated for their games.

Figure 1: Photos from Probability Carnival Capstone

5.1.3 Stop Animation Motion (SAM)

Stop motion animation is a technique that makes objects or drawings look as if they move on their own. The object or drawing is moved or changed between individual frames [8]. When the series of frames is played, it becomes an animation of the object or drawing. Groups of three students created a stop-animation video about Laws of Algebra, Equations and Formulae, or Pythagorean Theorem Word Problems to reinforce their learning and demonstrate it through explanation.

To introduce the process, students watched example stop motion videos and graded them using the class rubric for sets/characters/props, text, animation, sound/titles/credits, and topic explanation. After the grading exercise, a small group of students was chosen to create a shortstop motion video of Pacman using characters made of construction paper and a background created using a whiteboard. Students created the videos using Pico cameras borrowed from the Tufts CEEO and the demo version of SAM Animation software created by the Tufts CEEO. Examples of the videos are available at http://vimeo.com/user5225709/videos.

5.1.4 Short-Term Projects

At the end of the year, students completed a paper tower and fish & chips vs. the Fist of Doom as part of a teamwork development exercise. The students used paper from the recycle bin to create a paper tower that holds books without any tape, staples or glue. They followed a design process consisting of brainstorming, building, scoring (1 point for every inch above 11” and 1 point for every book the tower held), redesign, rebuilding, and rescoring. Students completed a reflection about how the engineering design process could apply to math class and about their learning.

For the Fist of Doom, students attempted to build the lowest-cost structure to protect a Pepperidge Farm goldfish and Pringle potato chip from being crushed by a heavy textbook dropped from a height of five feet. They worked in groups and followed a design process consisting of looking at the class market and brainstorm design, bringing a materials list to purchase from the market, building, testing, redesign, and retesting (see (Table 2). Example designs are pictured below in Figure 2. Most groups were able to protect the Pringle™ and goldfish during the first building phase, but when trying to cut costs down to win the class competition, all groups' structures failed.

Table 2: Example of Cost of Materials

Material	Price/Unit	Unit	Material	Price/Unit	Unit
Toilet Paper	$0.05	Square	Scotch Tape	$1.00	Foot
Corkboard	$10.00	Sheet	Yarn	$2.00	Foot
Clothespins	$0.50	Pin	Bulletin Board	$4.00	Foot
Packing Peanuts	$0.50	Peanut	Ribbon	$5.00	Foot
Ziploc Bags	$5.00	Bag	Bubble Wrap	$25.00	Foot
Ribbons	$0.05	Ribbon	Cotton Balls	$1.00	Ball
Duct Tape	$3.00	Foot	Cups	$30.00	Cup
Slim Masking Tape	$2.00	Foot			

Figure 2: Examples of "Protect the Pringle/Goldfish" Capstone Project Results

5.2 Technology Implementation

Unlike traditional math courses, technology courses have more flexibility in their curriculum design. The technology teacher at JQUS utilized colleagues within the CAPSULE program to strategize a unique and effective implementation plan for their respective classrooms. The teachers created an action plan centered on an extern, low-cost and portable USB power charger. Similar to any STEM subject, the capstone project had to be aligned with the Massachusetts Science and Technology/Engineering Curriculum Framework of Energy and Power Technologies – Electrical Systems.

As part of the implementation plan and student availability, the USB power charger needed to be a low-cost, portable, external and must be built from components not purchased as finish product. For this action plan, teachers found a Do It Yourself Kit (DIY) article for an USB power charger (see Figure 3) [9]. Teachers became very aware of the difficulty in acquiring workable materials at nearly no cost. Due to low or no budgets, many teachers had to be creative in how they acquired the necessary materials to implement their action plans. For this capstone project, students were required to understand how to read, measure, and calculate voltage, resistance, and power. Students were also required to understand the differences between a parallel versus a serial circuits. Not only were students required to create a working prototype, but they also had to learn to identify the components on a printed circuit board (PCB) and explain the relationship among voltage, current, and resistance in a simple circuit using Ohm's Law. Ultimately, this is the purpose of the CAPSULE program; to teach and allow teachers to create structured projects to educate and reinforce STEM theory.

As part of a capstone experience, each student creates a poster to illustrate the steps of the engineering design process and their proficiency in building the USB power charger prototype. Further, their presentation and oral communication skills are evaluated when they have to present their findings, work, results, and analysis.

Figure 3: Do-It-Yourself USB Charger

5.2.1 Classroom Execution

Prior to the major capstone project, the engineering design process was introduced to students to provide them with a systematic approach to problem solving. The first problem given to them was to design a catapult system that launched a Ping-Pong ball. The purpose of this project was to familiarize them with EDP as well as reinforce certain math concepts. Students were given this project with minimal constraints to create a solution that explained the acting force of the bridge of a catapult.

The capstone project for the Technology class was implemented in March 2011. Students were required to brainstorm a list of irritating daily problems. From this list, students and teacher were able to narrow down choices and discuss which problem is most reasonable to solve. Coincidentally, the majority of students found that power consumption was a problem with numerous electronic devices. With guidance from the teacher, students determined their capstone project would be to develop an external, low-cost, portable USB power charger.

Students utilized a multitude of sources to research the current industry and what devices already existed. Students used everything from the Internet to magazines to window-shopping. As a class, a list of possible USB power charger devices was created and a comparison matrix was created to compare features, cost, and efficiency.

For example, students compared an external portable USB charger from Radio Shack that supports only a specific phone while other devices found like HyperJuice [10] and ZAGGsparc 2.0 [11] lacked reasonable cost. Do-it-yourself (DIY) kits from MaximumPC did not have the correct voltage and the current on the USB pins were only for specific phones like the iPhone [9-11]. Two sources that were found and used were, 9V USB power charger from The Original Electroids Company and Minty Boost from Adafruit Industries.

Students analyzed both designs trying to understand and compare the efficiency, the electronic design, and functionality. Students determined that the 9V USB power charger uses a regulator to step down the voltage from 9 volts to 5 volts with a lost of efficiency from the device due to heat generated from the regulator. The Minty Boost on the other hand uses a step up transformer from 3 volts (from 2 AA batteries) to 5 volts.

9V USB Power Charger from The Original Electroids Company

The Original Electroids Co.

Minty Boost from Adafruit Industries

Figure 4: Do-It-Yourself USB Charger Student Prototypes

The class decided on the Minty Boost from Adafruit Industries as the solution to our problem. Students were able to learn and understand the details of the USB power source from the Minty Boost web site. As part of the CAPSULE program, teachers are provided with a materials stipend to be used on capstone projects implemented in their classrooms. For the USB power source project, parts and tools were ordered from Adafruit. Not only did students have to understand how the device worked, but also how to make the parts such a soldering and the construction of a PCB holder.

Each group encountered minor struggles in the completion of their power source however, the class wide issue was to secure the right type of tin for the enclosure of the components. The ½ size tin was not available at the time; therefore, we used the full size box as a substitute. The assembly and testing of the USB power charger kit took a total of three hours.

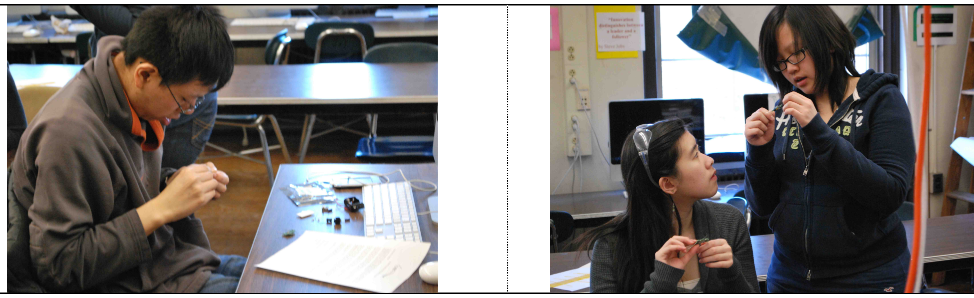

Figure 5: Students working on their respective Capstone Design Solutions

6 Student Experience and Feedback

6.1 Mathematics Capstone Project Student Feedback

Overall, students enjoyed the real-world focus, teamwork, competition, and creativity involved in the projects. They developed critical thinking skills and improved their leadership and collaboration. Major suggestions for improvement included more time for project development and testing, more materials, and troubleshooting/support for the SAM animation software. The students thought that the house design, product research and calculations involved in Habitat for Precalculus would be useful for them after college. They also enjoyed getting to customize the houses to their own preferences. Though students will likely never have to save a goldfish and a potato chip from a book in real life, one student stated:

> *"[It was] the most real-life thing we have ever done in math class. We [bought] stuff to make our 'shelter' for the chip, and all different things had different values. There was a lot of things to choose from that were very different from each other, so we had to pick and all agree on what were the best options to make our structure stand and cost less. It also had to do with building something sturdy enough to still stand after the book has been dropped from a certain height. It was kind of hard since we only had limited resources, but in the end my group… made the thing that was the least expensive and also supported the weight of the books drop."*

Another student stated:

> *"It really makes you think. Having the cost factor is not always a good thing because sometimes I don't get to use the items I want because I want to keep the price low. It really made me think twice about buying certain items. Our first design was just a roll of tape, which I bought for $30. That alone protected the chips from the fist of doom. This is the quickest and the most efficient way to protect the chips. When I redesigned, I tried to make it cheaper, so [my group would win]. I took the idea from [another group] where they put paper in the*

> *roll of toilet paper, … but [tried] to make it cheaper and protect the chip, by reducing the amount of paper we bought. Working in my group was great because I felt like I took the role of the leader."*

Students appeared to significantly benefit from the integration of capstone experiences that relate to their every day life. Students were very engaged in the creation and play of the probability games, even figuring out how to earn as much profit as they could as players. In one class, the profit could have been tracked more accurately and students noted that not all games were played with a similar amount of time. Other games did not succeed, such as the Wheel of Misfortune. Though the group brought in candy and noodles for their prizes, the dares on the wheel (e.g., touch another student's toes) ultimately proved too daunting for prospective players. For students, they began to analyze factors that influence decision making of people. One of the objectives was that students would begin to see the world differently and begin to understand and question why and how things are done. Although none of the students are legal to gamble, they had a slow realization why "the house always win".

For the table debates, one student noted:

> *"It was an extraordinary experience. It was still intense in spite of the small groups. The idea of rotating was creative and it wasn't like the usual classroom debates. Having the chance to judge the people in my group was entertaining because they [were] both engaged. Small debate groups seem to cause more participation from certain people because they may be afraid to speak up in front of the classroom… [it] was wonderful to see Vivian speak up more than usual because she came up with excellent arguments that was supported by evidence…[and the] debate pushed me to understand the skills on a different level." Similarly, for the full debate following the carnival, students were able to bring in probabilistic analysis to argue for their game to be chosen as the best while attacking other games.*

Unlike the carnival, SAM animation involved creation via technology rather than recycled materials. Students found it difficult at first, but soon became immersed in the process, even staying after school for hours to create and edit their projects. One student stated that SAM animation helps "us explore our [creativity and] help us understand math more in depth. It forces us to because in order to present our project…we must understand what we're working with. If I did not know what substitution was then the story concept in my stop animation would not had been relevant to [my goal of helping] people understand how substitution works in a fun way."

Students shared their creations during a "movie day" and were proud to show off their work and see what their peers had created. The project was repeated with another grade and the following school year. Students enjoyed it so much that they asked to start a SAM animation after-school club for creating animations such as public service announcements. However, students had the most difficulty with recording the audio tracks because the demo version of the software did not include editing capability; they had to record the tracks perfectly in one sitting.

6.2 Technology Capstone Project Student Feedback

Each student was required to participate in the project with deliverable. The majority of students decided to worked together as a team and produce their own extern USB power charger. Each student was responsible for different parts of the project such as: building the stand to hold the PCB, identifying the components, soldering and de-soldering, and customizing a case to house the parts for the USB power charger. The technology students learned to shared our limited resources: 5 PCB stands, 2 soldering irons, and 1 de-solder pump and understood the relevance of theory to application. Students learned to debug and trouble shoot common problems associated with manufacturing the USB power charger and got excited when they solved malfunctioning chargers.

This year's students were the first students to experience benefits of the CAPSULE learning model. The top-down engineering-based learning model is one technique of getting students to take ownership of their learning process. Students were able to take this method and use hand on experiences to accomplish unique solutions.

7 Conclusion and Future Work

Overall, incorporating EBL into the IB Math Studies classroom was a positive experience for student learning and improving the teacher's pedagogy. The pedagogy shifted from classroom lectures to open-ended projects, including more teamwork, analysis, presentations and writing than in previous years. Students who had tended to fail traditional assessments and not participate in class projects in the past became more engaged during class. Their quiz and test grades improved after participating in EBL projects, indicating a higher rate of concept retention. Writing and metacognition began to improve for all students. Other students who typically exceled on traditional tests and quizzes expressed discomfort with the open-ended assessments and the engineering design process. They were used to learning in a certain way and always scoring the highest in the class and EBL introduced unfamiliar territory for them. In many cases, the best EBL creations came from students who started out with the lowest test and quiz scores, which supports the need for more student-centered, student-controlled learning styles.

For the examples provided in this paper, the teachers continue to incorporate EBL in their curriculum. A few takeaways of CAPSULE and implementing new methodologies was preparation prior to the school year. Further, teachers were reminded to always expect the unexpected within their school and within educational politics. Additionally, it is important to leverage partnerships with higher institutions such as Northeastern University and Tufts CEEO to enhance student learning. Teachers of CAPSULE also better understand that higher institutions can provide additional resources for their classroom.

Specifically, the mathematics teacher in this paper plans to implement Google Sketchup™ as part of Habitat for Math Studies. She also plans to extend SAM animation to the engineering design process and leverage resources from iCreate to Educate in different types of activities (e.g., using time lapse to examine the growth of Orbeez or gummy bears and apply these to volume problems) [12].

The technology teacher plans to continue to refine his implementation plan for the following year. The project selection will possibly change due to a different interest of students however, he continues to stress engineering-based learning and the engineering design process.

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