Results from a Pilot Implementation of a Biomedical Engineering Program for Middle and High School Students (Evaluation)

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Abstract
The purpose of this study was to evaluate the efficacy of biomedical engineering curricula to teach the engineering design process and enhance students' ability to apply science and mathematical concepts to engineering problems. In this study, we developed and piloted five biomedical engineering (BME) lessons in six high schools. Students (n=91) were presented with biomedical problems, and then challenged to design a solution using clinical tools and STEM principles.
Pre- and post-surveys with 4-point Likert scales were administered immediately before (pre-) and after (post-intervention) students participated in the lessons. Surveys contained identical items to gauge students' perceptions of their: (1) knowledge of BME, (2) interest in BME, (3) ability to interpret trends in a data set, (4) confidence in making claims based on empirical data, (5) understanding of how doctors and engineers work collaboratively, and (6) knowledge of the application of mathematics to medical problems. Additionally, the post- survey included five items related to students' attitudes towards the five lessons. A pre-intervention baseline was not obtained since these post-intervention items related directly to students' levels of interest based on their participation in lessons.

Introduction

According to the National Math and Science Initiative, only 44% of 2013 U.S. high school graduates were ready for college-level mathematics courses and 36% were ready for college-level science courses (NMSI, 2016). In light of the rapid rate of technological advancement and globalization, these statistics seem grim. Creating a pipeline of highly qualified scientists, engineers, mathematicians, and technologists through high quality educational programs is the single most effective means for highly competitive workforce in these fields. Formal and informal STEM education, from preschool through postsecondary education, is a national investment for sustaining global competitiveness and addressing the challenges of the 21st century.

In the decade and a half, millions of K12 students have experienced some formal engineering education as part of regular school time curriculum (Kaheti, Pearson, and Feder, 2009). Although many of these programs have been successfully reached a substantial proportion of K12 students, only recently has there been a guiding framework systematically integrating engineering into the formal STEM curriculum – the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) – has been developed and adopted by 13 states. The NGSS is based on decades of STEM education research, which was synthesized in *The Framework for K12 Science Education* (NRC, 2012). The Framework formalized the integration of engineering into the major disciplines of science: life, earth, physical, and chemical. Unlike the previous National Science Education Standards (NRC, 1990), *The Framework* and the NGSS outline a learning progression of science and engineering practices for which students should develop increasingly complex skills as they progress from early elementary through high school. Moreover, *The Framework* and the NGSS outline grade level and grade band performance expectations related to engineering design. As a result, students are expected to engage in engineering design projects and engineering-related problems in their science coursework.

In an effort to address the need for high quality K12 engineering curricula, we developed, implemented, and piloted the *Biomedical Engineering Curriculum (BMEC,* a pseudonym for our program). BMEC curricula apply mathematics, science, physics, and anatomy concepts to orthopaedic case studies of patients with musculoskeletal injuries. The BMEC lessons aim to inform students of careers in biomedical engineering and orthopaedic surgery. As part our research and development, we piloted BMEC lessons with high school students from different schools and in different science courses. Our goal was to help students gain confidence with related math and science skills and be more compelled to consider STEM careers.

Research Questions

The purpose of this study was to investigate what changes, if any, occurred in students' knowledge, engagement and perceptions of their engineering skills as a result of participating in *Biomedical Engineering Curriculum (BMEC)*.

1) To what extent did students report the *BMEC* lessons as engaging and enjoyable?
2) To what extent did students' confidence in their ability to engage in engineering practices change as a result of participating in *BMEC* lessons?

3) To what extent did students' knowledge of biomedical engineering change as a result of participating in *BMEC* lessons?

Literature Review

Setting Standards for Engineering Education

In the past few years there has been a national focus on implementing engineering-based curriculum in K12 classrooms, yet many factors have historically limited the development and widespread implementation of K12 engineering curricula. These factors include challenges with providing large scale professional development to the current K12 teacher workforce, the integration of engineering curricula into established school curricula, the heavy influence of educational policies focused on standardized testing, and the absence of teacher certification and preservice teacher preparation programs in engineering (Kaheti, Pearson, and Feder, 2009). Prior to the *NGSS* and the *Framework for K-12 Science Education* (NRC, 2012) on which it's based, there was no cohesive educational standards for engineering in K12 classrooms. With the development and adoption of the NGSS, engineering has become an integral part of K-12 science education. Not surprisingly, a review of current engineering curricula revealed the treatment of key practices in engineering design, such as optimization, modeling, and analysis has been inconsistent or absent in mainstream K12 education (Kaheti, Pearson, and Feder, 2009).

Berland (2011) identified design principles for facilitating student application of mathematics and science concepts as they engage in the process of engineering. The first design principle is to contextualize all student work within STEM-design challenges. The second is to specify learning goals before designing specific lessons so that the lesson can actually meet those goals. The third is to employ a standardized engineering design process as an instructional framework. The fourth principle is to engage students in sensible forms of engineering design from the start. The fifth principle is to ensure all science and mathematics concepts, and technology tools employed are necessary for students' successful completion of the STEM-design projects. With these principles in mind, the next step is to examine classroom enactments of the curriculum, focusing on the extent to which students apply mathematics and science concepts to their design work and the challenges and affordances for doing so (Berland, 2013).

Effective Instructional Methodologies

Contemporary engineering education should emphasize the design process, challenge-based learning, and other engineering habits of mind (Berland, Martin, Ko, et al., 2013). The results of Berland, Martin, Ko, et al.'s (2013) study revealed that as a result of engaging in challenge-based engineering curricula students had a general sense of how engineers work, but they did not develop a deeper understanding of how to engage in engineering practices such as attending to user needs and working to meet design requirements. Moreover, the study showed students did not develop a solid understanding of the steps of the engineering design process that make the use of science and mathematics more relevant, and their use of mathematics and science concepts to engage in deep learning was also poor. Students often simplified the engineering design process by emphasizing the active steps over the analytical ones. They felt comfortable testing and building their design but not as much identifying the end user of their project or modeling the system. This study suggested two things must be in place for students to be authentically engaged in the engineering design process. First, it is necessary to develop activities that motivate and explain the value of the mathematical and scientific reasoning in the engineering design process. Second, lessons should reinforce mathematics and scientific concepts when they are relevant, but teach alternative decision-making processes and criteria when they are not (Berland, Martin, Ko, et al., 2013).

Martin et al. (2007) compared college students' learning in an inquiry-based and a traditional course on biotransport. The primary objective of the study was to identify instructional methods that facilitate the early development of adaptive expertise, that is, the ability to use knowledge and experiences to solve novel problems in an innovative way. Results indicated students in the inquiry-based course scored significantly higher than on both innovation and knowledge related items on the post-test than those in a traditional lecture group (Martin et al., 2007). The test had two components, one assessed knowledge, and the other assessed innovation. This study indicated that adaptive expertise requires a combination of two types of engineering skills: (1) subject matter knowledge and (2) the ability to think innovatively and tranfer skills to new contexts. Unfortunately, settings for traditional teaching are not conducive to development of these skills (Martin et al., 2007). Transmissional teaching hinders students' ability to develop innovation skills in a short period of time.

Cordray et al. (2009) examined whether a set of learning modules that involved challenged-based instruction improved student performance in a variety of educational settings and with diverse student populations. Findings indicated that curriculum developers were more successful than those individuals who simply adopted and implemented the curriculum. Findings also indicated notable differences between college and high school students that could not be attributed simply to differences in cognitive development. Instead, differences in student performance were better explained by demographic variables such as gender, race, ethnicity, family's educational background, and socioeconomic status.

English et al. (2013) reported findings from a STEM-based lesson in which students explored engineering concepts and principles pertaining to simple machines. The students clearly indicated how the machines were simulated by the materials. The students were also able to reflect on different aspects of their design, especially on material properties and how they affected stability. Allowing students to suggest ways to improve their designs provided opportunities for further reflection in subsequent design processes. In general, students did not make explicit references to underlying engineering and science principles, but they were able to link physical resources to science concepts and design criteria and constraints.

Engineering and The Leaky STEM Pipeline

The leaky STEM pipeline, which includes engineering, is a metaphor that represents the lack of retention and persistence of females and minorities in the STEM fields (Rask, 2010). Montford et al (2013) asserted the problem is partly related to the lack of relatable course content and students' pre-existing beliefs about the field of engineering. In particular, students' beliefs about the field of engineering suggest persistent misconceptions that influence important in career choice decisions. Students who are interested in pursuing engineering generally believed that it involved building or fixing cars, bridges, and airplanes. Students, especially female, who were not interested in engineering discussed a broader variety of types of engineering, and more often cited altruism and inherent interest in other subjects as reasons why they did not pursue engineering (Montford et al., 2013). Seymour and Hewitt (1997) had similar findings – 90% of women and minorities cited choosing a field of study in order to help others during their careers.

Persistence and retention of females and underrepresented minorities in engineering fields is complex; it involves the interplay of factors beyond which can be explained by students' beliefs and interest. For instance, Chesler et al. (2010) found experience with diverse peers early in college years fosters more positive, cross-racial interactions. Students with the most classroom experience with diversity and most diverse friends and experiences on campus are more engaged in learning, and self-reported more gains in critical thinking, problem solving, and self-confidence. The main barriers to women in science and engineering are: (1) the pipeline needs to grow, (2) the departmental climate has a hostile "macho" culture that is isolative, (3) difficulties balancing family and work since family caretaking responsibilities fall disproportionately on women, (4) unconscious bias combined with subtle negative interactions. According to Hewlett et al. (2008), 52% of highly qualified women working for science, engineering, and technology-related companies leave mid-career due in part to hostile "macho" cultures and isolation in the workplace. Some of the issues limiting the retention of women in engineering and other STEM fields have been expressed and brought up for serious discussion.

Knowing more about what aspects of science and engineering appeal to different groups of students, how aspirations may change over time, and what student characteristics are linked to success are useful in creating more effective curriculum and interest for STEM amongst underrepresented groups, including women. In Ing et al.'s (2014) study, females who expressed interest in engineering were less consistent in their interest than males for the duration of the study. Only one female (<1%) was consistently interested in an engineering career across all three years compared to 20 males. Knowing an engineer was a significant predictor of the degree of consistent interest in an engineering career. Females and males expressed similar levels of interest in careers in which they discover new things that help environmental or human health. Sadler et al. (2012) showed the number of males choosing to pursue a degree in STEM remained fairly stable throughout high school; for females, however, there was a decrease in the number choosing STEM careers from the beginning the end of high school. These studies and others (e.g., Dabney et al., 2013; Lindahl, 2007; Maltese and Tai, 2011) collectively indicate that the majority of students know what career they will pursue by high school. Access to high quality opportunities to engage in STEM learning advance and reinforce students' interest in STEM and their future career choices (Tyson et al., 2007; Wang 2013).

Once in the field, how do we keep exceptional female talent going through the pipeline? A call to action to investigate the trends in the roles of women in biomedical engineering has been made. There is a lack of data on biomedical engineering-specific barriers to the retention and advancement of women and people of color. The issues identified were identified based on a review of previously identified barriers in STEM disciplines.

Methods

The goal of this study was to determine the efficacy of a unique biomedical engineering curriculum for enhancing students' interest and knowledge of skills required for pursuing study and careers in engineering. In light of the "leaky STEM pipeline" outlined above, we endeavor to create meaningful, real world learning opportunities for middle and high school students to engage in biomedical engineering. Our motivation for this project is to provide curricula that integrate knowledge and skills useful across different field in STEM and are applicable in a variety of middle and high school courses, such as physics, health sciences, mathematics, and engineering.

Context and Data Sources

Biomedical Engineering Curriculum (BMEC) is a unique, hands-on curriculum for middle and high school STEM classrooms that presents real-world challenges from orthopaedic surgery and biomedical engineering. BMEC features five stand-alone lessons (Table 1). Each interactive lesson presents a unique case study. Students must conduct clinical and biomechanical experiments to determine the best treatment for the patient. Each lesson consists of a PowerPoint presentation, student worksheet to collect data and carry out an analysis, and a hands-on model on which the testing is performed. Complete instructor professional development materials are also included. These materials consist of written lesson plans, student worksheet solution keys, and training videos of example lessons and in-class exercises. Each lesson is mapped to at least one **disciplinary core idea** (DCI) from the *Next Generation Science Standards* (NGSS).

Pre- and post-surveys were administered to student participants immediately before and after BMEC lessons (n=91). Student participants were recruited from six different high school classrooms in four school districts in the mid-Atlantic United States. Pre- and post-surveys contained five identical items in order to analyze changes to students' perceptions before and after participating in BMEC. Identical questions included items to gauge students' perceptions of: (1) their knowledge biomedical engineering, (2) their interest in biomedical engineering, (3) their ability to interpret trends in a data set, (3) their confidence in making claims based on data trends, (4) their understanding of how doctors and engineers work together, and (5) how mathematics can be applied to medical problems. Additional questions pertained to students' perceptions of their level of enjoyment during the activity, wanting to do more similar activities, how interesting the activity was, and their desire to learn more biomedical engineering. The two sets of surveys had identical items, the only difference was that one had a four-point scale and the other had a five-point scale. The five-point scale included a "neutral" option while four-point scale did not.

Data Analysis

With SPSS V19 (2013), all survey scale scores were analyzed using descriptive statistics. In addition, mean responses for identical pre-/post-scales were compared using one-way ANOVA with repeat measures to determine if there was a significance difference in participants' perceptions of their knowledge and skills before and after participating in *BMEC* and Cohen's *d* was computed to determine effect size.

Table 1
Overview of the *Biomedical Engineering Curriculum (BMEC)* lessons

Name	Overview	Student Activities
Scoliosis Diagnosis	Determine the severity of a patient's scoliosis by measuring spinal curvature lateral and anterior-posterior view x-rays, and then recommend a treatment plan based on data.	Learn basic spine anatomy Use knowledge of anatomy to assemble x-rays Measure magnitude of patient's spinal curve Use basic geometry and statistics
Repair that Tear	Repair a torn Achilles tendon using two different suturing techniques and perform a mechanics stress test. Based on data, recommend a suture technique that takes advantage of the tendon microstructure.	Learn basic about the mechanical properties of the Achilles tendon Suture a ruptured tendon using the two suturing techniques Perform a stress test (Creep test) in for each technique
Get a Grip	Learn about the tendons in the hand that function as pulleys to allow the hand to articulate. Observe the force ratio in the forearm and at the finger tip for different grips.	Learn basic anatomy Assemble the tendons and sheaths in the hand that function as pulleys Measure force input at the forearm and fingertip and calculate ratio to see which grip is the most efficient
Anatomy of a Knee Injury	Learn about the four main ligaments in the knee and learn how they limit motion in different directions. Learn about ligament injuries and diagnostic tests performed by a doctor. Perform these tests on a knee model to diagnose a patient's injury.	Learn basic knee anatomy Learn about knee ligament injuries and diagnostic tests Perform tests and quantify displacement of the bones Based on tests, diagnose a patient's ligament injuries
Engineering an Ex-Fix	Learn bone anatomy and how different loads cause different fracture patterns. Repair a fractured tibia with two different external fixator arrangements. Apply forces and based on movement at the fracture site, choose the best design.	Learn basic bone anatomy Learn about bone fracture fixation methods and use an external fixator to repair a tibia Test different ex-fix designs and recommend one to the doctor that will keep the bones in place

Findings

Pre- and post-survey results indicated that significant differences in students' perceptions of their knowledge and interest in biomedical engineering from pre- to post-participation (see Figure 1 and Table 2). There was a significant increase in knowledge about what a biomedical engineer does [$F(1,132)=18.37$, $p<0.0001$]; prior to participating in BMEC, the mean students response to knowing what a biomedical engineer does was disagree ($M=2.03$, SD=0.74) and after participating in BMES, the mean response was closer to agree ($M=2.75$, SD=1.15) The effect size of the treatment was large ($d=0.74$, $r=0.466$). There was also a significant increase in students' interest in pursuing a career in biomedical engineering [$F(1,125)=13.45$, $p=0.0004$], the mean response increasing from the pre-condition ($M=1.79$, SD=0.72) to the post-condition ($M=2.24$, SD=0.80). The effect size of the intervention was moderate ($d=0.65$, $r=0.218$). There was a significant increase in students' understanding of how doctors and engineers work together [$F(1,143)=33.37$, $p<0.0001$], with the mean response increasing from pre-condition ($M=3.49$, SD=0.60) to the post-condition ($M=3.94$, SD=0.24). The effect size of the treatment was large ($d=0.98$, $r=0.325$).

In the pre- to post-conditions there were significant differences in students' perceptions of their science and engineering process skills. For instance, mean response related to students' ability to interpret trends in a data set [$F(1,143)=12.73$, $p=0.0005$] increased from pre- ($M=3.32$; SD=0.59) to post-condition ($M=3.48$, 0.66). Students also increased in their confidence in making claims based on data trends [$F(1,143)=10.96$, p=0.0012] with the mean response increasing from $M=3.48$ (SD=0.66) to $M=3.79$ (SD=0.44) with moderate effect sizes ($d=0.60$ and 0.56, respectively). Students did not not significantly increase their understanding of ways in which mathematics can be applied to medical problems ($p>0.05$) from pre- ($M=3.70$, SD=0.54) to post-participation in BMEC ($M=3.79$, 0.44).

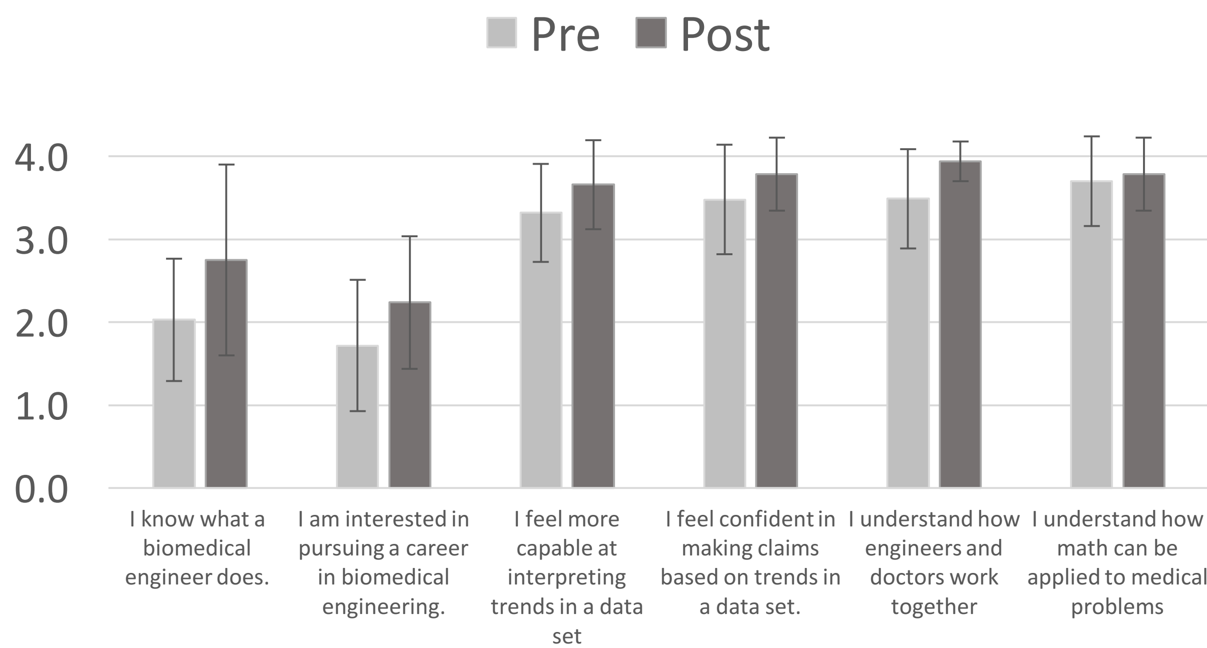
Table 2

Comparison of students' pre- and post-intervention responses to survey items on a four-point Likert scale (Strongly Agree=4; Agree=3; Disagree=2; Strongly Disagree=1). ***RQ*** *indicates the research question to which each survey item was correlated.*

		Pre		**Post**	
RQ	**Pre/Post Survey Question**	***M***	**SD**	***M***	**SD**
3	I know what a biomedical engineer does.	2.03	0.74	2.75	1.15
1	I am interested in pursuing a career in biomedical engineering.	1.72	0.79	2.24	0.80
2	I feel more capable at interpreting trends in a data set	3.32	0.59	3.66	0.54
2	I feel confident in making claims based on trends in a data set.	3.48	0.66	3.79	0.44
3	I understand how engineers and doctors work together	3.49	0.60	3.94	0.24
3	I understand how math can be applied to medical problems	3.70	0.54	3.79	0.44

Figure 1

Comparison of students' pre- and post-intervention responses to survey items on a four-point Likert scale (Strongly Agree=4; Agree=3; Disagree=2; Strongly Disagree=1). SD bars shown for each item in the pre- and post-condition.



The post- survey included five questions pertaining to attitudes towards the engineering lessons. A baseline was not obtained since these questions related directly to students' levels of interest based on their participation in the lessons. On average, students enjoyed hands-on engineering lessons, they enjoyed these specific activities, would like to do more activities like these, and found the activity interesting. On average, students also agreed that they would like to learn more about the topics on which the activity focused (see Table 3).

Table 3

Descriptive statistics of survey items pertaining to students' attitudes and levels of intere the four-point scale (Not at all = 1; A little bit = 2, Somewhat = 3; A lot = 4). RQ indicate research question to which each survey item was correlated.

RQ	Post-Survey Question	*M*	SD
1	I enjoy hands-on activities like this one.	3.88	0.32
1	I enjoyed doing this activity.	3.82	0.38
1	I would like to do more activities like this.	3.78	0.45
1	This activity was interesting to me.	3.81	0.40
1	I would like to learn more about this topic.	3.68	0.53

Discussion and Implications

As engineering educational programs continue to grow, more research is warranted to study their efficacy. In this study we evaluated the influence of BMEC curricula on students' knowledge of engagement in biomedical engineering. Similar to Berland et al., (2009) the purpose of this study was to assess the effectiveness of using challenge based curriculum to achieve the following goals: (1) teach students the engineering design process and (2) to deepen student understanding and ability to apply science and mathematical concepts. The BMEC curriculum is an example of a challenge-based curriculum as it was designed to use engineering and science concepts to solve an orthopaedic challenge. Students were presented with the clinical problem and relevant background information as well as the implications of their work on patients' well-being. For example, in the lesson *Engineering an Ex-Fix*, students were introduced to a patient that had a fractured tibia. The students were asked to design different external fixator scaffold arrangements and perform mechanical stress tests to quantify which design was the most stable. Based on testing and data collection, students recommended a treatment plan. The arrangement of the external fixator hardware was not random, but rather chosen based on force and motion principles. Through ex-fix design and re-design, students learn that placing pins closer to the fracture site reduces the moment arm and rotation at the fracture site, making the arrangement more stable.

In Berland et al. (2009), students were engaged in design work before given the pre-survey, which made it difficult to ascertain whether students entered the course with already sophisticated beliefs about the engineering design process or if those beliefs developed over the course of the program. Similarly, the BMEC curriculum was piloted at six different high schools and in different courses. The classrooms included a robotics/engineering course, an introduction to physical therapy course, and an anatomy and physiology course. The data were not segregated by course during data analysis in this study due to small sample sizes in each course. However, previous research indicates that students' background knowledge and experiences have an effect on their performance and perceptions of learning activities (Bransford, Brown & Cocking, 1999).

Our data revealed, overall, a significant increase in student confidence in interpreting data, making claims based on data, and knowledge and interest in biomedical engineering (Tables 1 and 3). Similarly, Berland et al. (2013) reported in a similar manner that students did not develop a solid understanding of the steps of the engineering design process that contextualize mathematics and science practices, The BMEC curriculum was successful in presenting relevant application of mathematics and science concepts and reinforcing those concepts when they were relevant, but did not teach alternative decision-making processes and criteria for when such concepts were not relevant. The short duration of the BMEC lessons, 60 to 90-minute class periods, could explain the limited influence of the lessons on these skills.

Studies like Cordray, Harris, and Klein, (2009) inform the development and revisions to the BMEC curriculum. Similar to theirs, our BMEC lessons are challenge-based; it is our hope that BMEC lessons will be adopted in a variety of classrooms with students from diverse backgrounds so that we can further test the efficacy of the curriculum for promoting the knowledge, skills and awareness of engineering design and engineering professions. During the pilot phase of curriculum development, BMEC developers taught the lessons; as such, these instructors were well versed in the lessons and had ample experience with the topics in each BMEC lesson. Once the lessons are broadly distributed, it will become imperative to track whether or not the same student outcomes are generated when K-12 teachers facilitate the lessons. With this in mind, all BMEC lessons contain detailed written reference materials and instructional videos and additional data will indicate the utility of these professional development materials. Another important point raised by Cordray et al.'s (2009) study is that challenge-based curriculum may be new to students and may be more difficult than traditional instruction. Enhancing teachers' pedagogical skills for supporting student learning in a challenge-based environment will be essential for the success of the curriculum.

Lessons learned from Bransford, Brown and Cocking (1999), who indicated the critical interplay of teachers, learners, and learning environments, can be used to inform subsequent study of the BMEC curriculum. Teachers need a teaching framework as well as expertise in their subject and teaching. Learners require a coherent understanding of the organizing principles in any subject matter. They also need a deep detailed knowledge of the facts within a domain. The learning environment should encourage feedback, opportunities for failure and continuous improvement. Similar to the instruction in Martin et al. (2007), the BMEC lessons are hands-on and promoted active feedback and collaboration between students and instructor. Students also learn relevant background information that helps them solve the challenge presented at the beginning of each lesson, thus reinforcing this knowledge.

Katehi, Pearson, and Feder (2009) argued it is important to keep developing engineering education because evidence shows that engaging elementary and secondary school students in learning engineering ideas and practices yield positive learning outcomes. The most intriguing potential benefits of K12 engineering education relate to improved student learning and achievement in mathematics and science and enhanced interest in these subjects because of their relevance to real world problem solving (Katehi et al., 2009). Likewise, these are the essential features of the BMEC curriculum. Science and engineering concepts are directly applied to a clinical problem. Since the application of these principles is related to the human body, BMEC curriculum situates engineering in meaningful contexts.

Conclusions and Future Work

In this paper, we presented an analysis of limited data on the efficacy of BMEC for promoting students' knowledge, skills and awareness of biomedical engineering. Our data indicated efficacy of BMEC curriculum on students' perceptions of their knowledge and engagement in STEM. Clearly, early intervention of students to enter engineering is extremely important when considering current challenges in engineering education. The percentage of women for example obtaining BS, MS, and PhD degrees in biomedical engineering is higher than nearly any other engineering discipline, but graduation rates have not steadily increased over time and past graduation rates have not led to higher percentage of women in faculty positions (Chesler et al., 2010). The STEM pipeline is leaky with regard to engineering, and current trends will continue unabated without directed intervention at different levels (Chesler et al., 2010).

Future research should focus on assessing the effects of the BMEC curriculum on those targeted groups. The data set analyzed in this report was not separated by demographic variable and the number of participants was small. Once the curriculum is implemented in more classrooms, additional dimensions of the student population can be analyzed. The most significant influence of the BMEC curriculum was its informative nature. Students overwhelmingly reported increased awareness of biomedical engineering. We also saw a significant increase in the number of students that wanted to pursue careers in biomedical engineering. These findings demonstrate that informing students about engineering fields is an important first step in increasing the number of students that pursue these fields.

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