AC 2010-768: INTEGRATING ENGINEERING TO MIDDLE SCHOOL CURRICULUM BY TRAINING TEACHERS

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Integrating Engineering to Middle School Curriculum by Training Teachers

ABSTRACT. Providing K-12 students an earlier exposure to engineering is recognized as a way to prepare them for postsecondary courses. There has been a significant increase in academies and workshops addressing this concept. Since there is a total turnover of students each year, training K-12 teachers has been thought as an efficient approach. Further, teachers can integrate engineering concepts during the academic year which provides a natural transition. Based on this concept, two middle school teachers (teaching Biology and Math) were selected to participate in research dealing with tissue engineering. Teachers worked for six weeks (four days a week) within the research laboratory on formation of porous structures using biodegradable polymers. Teachers were exposed to the technique of forming porous structures using chitosan and gelatin solution in various shapes using the apparatus available in the laboratory. A low cost freeze drying system that is safe for operation by sixth grade students was developed. The overall cost of performing the experiment is also significantly cheap and less time consuming.

An envisioned project for the current academic year under implementation in the sixth grade is freeze drying chitosan-gelatin solutions. Biology teacher will ask the students to make scaffolds that can support the regeneration of various body parts. First, students will perform a survey to determine available biodegradable materials for use in the body along with cost estimation. Once they determine what polymer they need, then they will freeze and air dry the premade chitosan-gelatin solution to form films and porous structures. Here, students will make scaffolds of shape and dimension that mimic a specific body part. Students are also asked to evaluate the number of pores using digital scanning electron micrographs. We anticipate that the entire hands-on experience will stimulate their interest towards engineering or STEM fields.

INTRODUCTION

Many recent surveys indicate disinterest in engineering career by nearly 85% of 8 to 17 old students [1]. A major reason cited by the students is the lack of awareness about engineering. As most students advance through middle school science classes, their attitude toward science become more negative and their interests decrease most in the seventh grade [2-5]. Thus, the middle grades are a critical period for students, representing the period most beneficial to provide engaging academic opportunities. With the increase in demand of qualified engineers, the lack of interest has been thought as future problem.

There has been a significant increase in academies and workshops to provide an early exposure to engineering, which is recognized as a way to prepare K-12 for postsecondary courses. Focusing on teachers and students in the middle grades targets a population which is not being served by existing local outreach activities. While there are several programs focusing on students and teachers in high school, for example Project Lead the Way [6], there are few designed for lower grades. Since there is a total turnover of students each year, training K-12 teachers is an efficient approach. Further, teachers can integrate engineering concepts during the academic year which provides a natural transition. Based on this concept, Transitioning Engineering Research to Middle Schools (TERMS) was initiated. TERMS draws STEM middle school teachers from local school districts in north-central Oklahoma; Stillwater Public Schools resides in the same community as Oklahoma State University. TERMS builds on a large body of
Applications were solicited in the middle school through the superintendents of different locality. The application process was designed to identify teachers that were interested in introducing engineering skills to math and science classes. Preference was given to teachers that have shown interest or ability in inquiry-based pedagogy. The applicants were also asked for their commitment to the pre- and post- summer academic year activities. Upon review of applications, six participants were selected in the first year of TERMS from math, science or technology teachers in 6th-7th grades. One unique feature of TERMS was pairing teachers with undergraduate students (referred as REU students in the subsequent discussion) to bridge gaps between the knowledge and experience of faculty and teachers. REU students were selected for this project from the engineering programs, so that they are comfortable with instrumentation and understand measurement procedures that may not be familiar to teachers. REU students were also required to continue to work with teachers during the fall semester to help implement engineering research knowledge in the classroom.

**EXPOSURE TO THE RESEARCH TOPIC.**

Teacher activities were divided into three periods: a spring pre-visit, summer campus visit, and post-visit activities. Pre-visit activities occurred two months prior to the summer research activity. During the pre-visit period teachers were engaged in professional development activities with the faculty. These activities were designed to inform teachers about engineering and its role in society, provide an overview of the research focus to help teachers select advisors and projects for the summer, and to begin project assessment.

The first set of pre-visit activities was to familiarize teachers with engineering. Discussion topics included how engineering activities address content standards; how engineering is part of everyday life; and how to effectively integrate multimedia, writing, and computer skills into the classroom. The second pre-visit activity was focused on identification of research projects that teachers felt appropriate for their course goals. During the pre-visit, teachers met with the faculty, listened to a presentation on the research activity of the faculty member and toured the research laboratories. During this time, teachers were given an overview of tissue engineering and mechanisms at the molecular level that trigger cellular processes in stem cell differentiation and proliferation, in regenerating tissues, and traumatic conditions. Importance of 3D architectures to optimize scaffolds for cellular growth to regenerate tissues was also discussed. Pre-visit activities were used to identify interests of teachers in a particular research. Based on these activities, two teachers (one teaching biology and the other teaching mathematics) were assigned to a project dealing with tissue engineering.

**SUMMER ACTIVITY.**

REU student who was selected primary for this project began the summer session two weeks prior to teachers. During the first two weeks, REU student was introduced to the basics of using laboratory instrumentation and software. REU student was exposed to the concept of freeze drying and formation of porous structures using biodegradable polymers. Further, REU student also utilized the commercial freeze drier available in the research laboratory. One of the first tasks of the REU student was to develop a freeze drier that could be utilized in the middle school. After many trials and discussion with the faculty mentor, REU student developed a low cost freeze drier that is safe for operation by sixth grade students (Figure 1). The overall cost of...
performing the experiment is also significantly inexpensive and less time consuming. Also, polymers to be utilized were less expensive.

Teachers worked for six weeks (four days a week) within the research laboratory on formation of porous structures using biodegradable polymers. The following structure was used:

- Each week there was one meeting between the faculty mentor, teacher, and REU student to discuss the research objectives and direction to pursue.
- During lunch on Monday through Thursday the entire teacher-REU students would meet to discuss their research.
- Every Friday for the first four weeks and Thursday/Friday during the last two weeks the teacher-REU students worked on transitioning their research to the classroom. These days were included for professional development talks by College of Education faculty, discussions led by engineering faculty who have successfully integrated research into undergraduate courses.

Teachers were exposed to forming porous structures using chitosan and gelatin solution in various forms using the apparatus available in the research laboratory. During the discussions with the faculty mentor, many topics related to tissue engineering, use of different types of cells and polymers were discussed. The key focus on these days was to learn from faculty the process through which engineering research knowledge is integrated into courses. Further, some of the required equipments for the project were also purchased and prepared. For example, pipettes, magnetic stirrers, small vacuum chamber and weighing machines were purchased. Also, a small stand where samples can be placed by many student groups simultaneously was constructed.

**PROJECT PLANNING.**

An envisioned project the sixth grade students would work on during the academic year was freeze drying chitosan-gelatin solutions. Biology teacher would ask the students to make scaffolds that can support the regeneration of various body parts. Students would survey in the beginning to determine what polymers would be best for use and why. Once they determine what polymer they need, then they will freeze and air dry the premade chitosan-gelatin solution to form 2-D and 3-D structure. Math teacher would help them understand the pore size, pore...
number and void fraction calculation using scanning electron micrographs given by the PI. Students would be asked to make scaffolds that can mimic a specific body part. The students would perform three different experiments with the Chitosan and Gelatin solutions. They would first air dry polymer solutions to create a 2-D membrane. The students would then create a 3-D porous structure using the freeze dryer built in the laboratory. Cells can then be seeded on to the structures. Cell colonized structures can be used in biomedical applications such as skin grafts (2-D), and replace damaged tissues within the body (3-D). For the last experiment the students would pour their solutions into a baby food jar and place it in a freezer until the solution freeze dries. This process leads to the same result as using the vacuum pump but, will take much longer for the solution to freeze dry. The math research will consist of a cost analysis of certain biodegradable polymers to determine which ones would be best to use. Once the freeze drying of the Chitosan-Gelatin solution is finished, they will be given a picture of the pores of the 3-D porous structure which was taken by a scanning electron microscope. They will then learn how to calculate and evaluate the pore size, pore number and void fraction calculation.

IMPLEMENTATION IN THE MIDDLE SCHOOL.

Biology teacher introduced the project to the students as an extension of the required curriculum covering cells in sixth grade biology course. It was an extremely natural flow of information. All of the content that covered about cells was background information and research in the engineering cycle. A STAR was put in front of all of the titles of the lessons that pertained to the project. Also, terminologies related to the project referred to as “Working Vocabulary” instead of the “vocabulary.” According to the observation of the teacher, the kids liked that aspect. Biology teacher had told the students weeks prior to the project that they were going to be doing a phenomenal engineering project, but refused to tell them what it was. When the brand new deep freeze arrived (purchased from the school budget) for the purpose of the project, and the teacher told the students that it was for the engineering project, they got REALLY EXCITED! These events led to the discussion about engineering in general i.e., the different types, job opportunities, familiarity with the fields due to family members being engineers, etc. Then the students got to know the REU student, who told them what he was going to be doing with the course and what teachers had done during the summer in preparation for this project. The kids really responded positively to the REU student. During the modeling phase of the project (the actual mixing, pouring, and processing of the samples), the teacher did a demonstration of some different kinds of mixtures/solutions with the final one using gelatin as one of the ingredients. Teacher did this so that the students would experience what property that polymer would be bringing to the final product. This simple demonstration was hugely instrumental in the kids’ excitement to move ahead with the project. According to the teacher, the experiment could not have gone better! Simple instruments such as magnetic stirrers, pipette aids, digital weighing machines are exiting for students. REU student was present during the day that students did the mixing pouring freezing and freeze drying (Figure 2). It would be difficult for one teacher to get everything done in the allotted fifty minute class time without additional hands. Presence of additional hands is instrumental in the success of the day! Coordinating all the activities may be overwhelming. Freeze dried samples from the inexpensive apparatus using the vacuum pump turned out to be INCREDIBLE!!!!!! According to the teacher, they turned out even better than the samples that were produced in the laboratory during the summer activity.

Freeze drying is a slow process, particularly in the absence of a vacuum pump. Thus, some experiments were carried through the Christmas break. However, students were continuously
monitoring some of the samples upon their return until they freeze dried. The teacher used this opportunity is a positive way by revisiting the concept that real engineering projects take long time. Further, concept of redesign to address specific problems could also be addressed. At this juncture, no formal written input has been obtained from the students. However, judging from their comments during the different phases of what the project, it is more than safe to say that they LOVED this project! Some of the motivational writings that teacher had them do prior to the fabrication of the solutions were absolutely inspiring!

According to the biology teacher, the things that were planned during the summer activity took on a whole different reality when the students were present. The summer planning is like the “wish list.” The classroom implementation is the “real world!” The project extended beyond the initial planned period, which lead to some interruptions from other obligatory lectures. This could cause some inconvenience and adjustment in the teaching schedule. Overall, the biology teacher expresses that “WE ROCKED THIS PROJECT!!” The biology teacher is planning to do this next year without the help of the REU student. The math teacher is integrating some of the research component into the curriculum. However, it has been a significant challenge relative to the biology course. From the PI’s perspective, it has been a self learning experience to introduce cutting edge research concepts to middle schools.

**SUMMARY:** Teachers benefit from multiple perspectives offered by having both faculty mentors and REU student collaborators. The combination of engineering design skills brought
by the REU student and focus on pedagogy and content need by teachers will have great benefit to both participants. The experience will also be more transformative on the REU students if they also have to teach. From a practical perspective a longer employment period is needed to attract REU students who otherwise would take summer internships. The additional period also benefits the project since the REU student can continue to work with the teacher to solve technical issues that arise once the teacher begins to implement the research problem at their home school. This additional time will also result in more students obtaining publishable results from their research. We anticipate that the entire hands-on experience will be a positive reinforcement to their creative learning experience and encourages them to biomedical engineering/sciences. After successful implementation within the middle school the developed modules will be shared through the development of a website.

This is the first year of the project. In the next phase, we are extending this concept to four teachers. Also, some of the teachers are returning in the next summer to help train other teachers and implement the program more effectively. Based on the interaction with mathematics teachers, alternative projects are planned in the next year.

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REFERENCES:

