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BOARD # 23: Work in Progress: Development of a Teaching Module to Elicit Retention of Conceptual Learning in the Biomedical Engineering Discipline for High School Students

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Papadopoulos has diverse interests in structural mechanics, sustainable construction materials (with emphasis in bamboo), engineering ethics, and engineering education. He is co-author of Lying by Approximation: The Truth about Finite Element Analysis, and after many years, he has finally (maybe) learned how to teach Statics, using an experiential and peer-based learning "studio" model. As part of the UPRM Sustainability Engineering initiative to develop a new bachelor's degree and curricular sequence, Papadopoulos is PI of A New Paradigm for Sustainability Engineering: A Transdisciplinary, Learner-Centered, and Diversity-Focused Approach, funded by the NSF HSI program. Papadopoulos is active in the Mechanics (former Chair), Ethics, and LEES Divisions of ASEE, and is the co-president of the UPRM Institutional Committee for General Education. He enjoys biking, swimming, cooking, and eliminating disposable plastic.

Papadopoulos endeavors to orient his research and teaching activities around advancing, peace, social equity, justice, and human wellbeing. In the words of Roberto Clemente, anytime when you have the opportunity to make a difference in the world, and you don't do it, then you are wasting your time on earth.

Work in Progress: Development of a Teaching Module to Elicit Retention of Conceptual Learning in the Biomedical Engineering Discipline for High School Students

Introduction

Hands-on activities implemented in the classroom can be beneficial for students to reinforce their learning and concept retention [1]. In previous works, it has been demonstrated that high school students need guidance to learn new concepts in biomedical engineering courses, for example to help them navigate potential frustration during the learning processes [2]. For this reason, it is also important to carefully design hands-on activities to promote a positive interest and motivation in students to perform the activity and hence to learn from it [3] [4]. Teaching modules can be created to increase student learning in STEM concepts, using activities that students can enjoy while learning mathematical reasoning [5], suggesting that this can be used to promote conceptual learning and retention. Moreover, well-planned workshops can also help improve scientific skills, promoting a better understanding of STEM concepts [6]. This work hypothesizes that teaching modules that include hands-on activities can enhance concept retention in the BME field, by allowing students to learn and retain the concepts to later be able to apply them to a real-life application in BME.

Description of Module

A teaching module to help high school students to learn and understand concepts from biology and mathematics and apply these concepts to a BME application is presented. Students interacted with equipment and materials used in the laboratory and were able to experience practices as used in real laboratories, focused on two basic scientific fields, mathematics and biology. The workshops were built in a way that allowed students to apply these basic science concepts to an advanced biology or engineering application (college level), which students had not previously studied. The module is organized in three workshops:

(1) Functions of human body cells: Students learned the components of the cell and their functions; for example, they learned how the cells secrete proteins. They identified first the nucleus, then the Reticulum Endoplasmic and finally the Golgi apparatus. They also learned how the morphology of the cell looks, depending on the type of cell and localization in the human body.

(2) Microscope functioning: The students observed different types of cells prepared on cover glass, using magnifying glasses and a light microscope. The students observed cells and tissues and compared microscope resolutions to observe cells and tissues.

(3) Determination of a spring constant in relation to tissues in the human body: Students learned how to estimate the spring constant of a rubber band using a simple setup of rulers and markers that allowed them to identify how much the rubber band stretched after loading it with a specific amount of weight. Then the students used mathematical equations to estimate the spring constant.

All the activities were carried out with safety equipment (Covid-19 masks, glasses, gloves, and lab coats). Each workshop (hands-on activity) contained a designed practice for each concept. First, a short talk of a real application of the concept was delivered, afterward students worked in teams of 2 or 3 students in the hands-on activity and filled out a set of questions as a team. After the students were done, a group discussion was held and finally they took the short test a day or two after the workshop. Figure 1 illustrates this methodology.

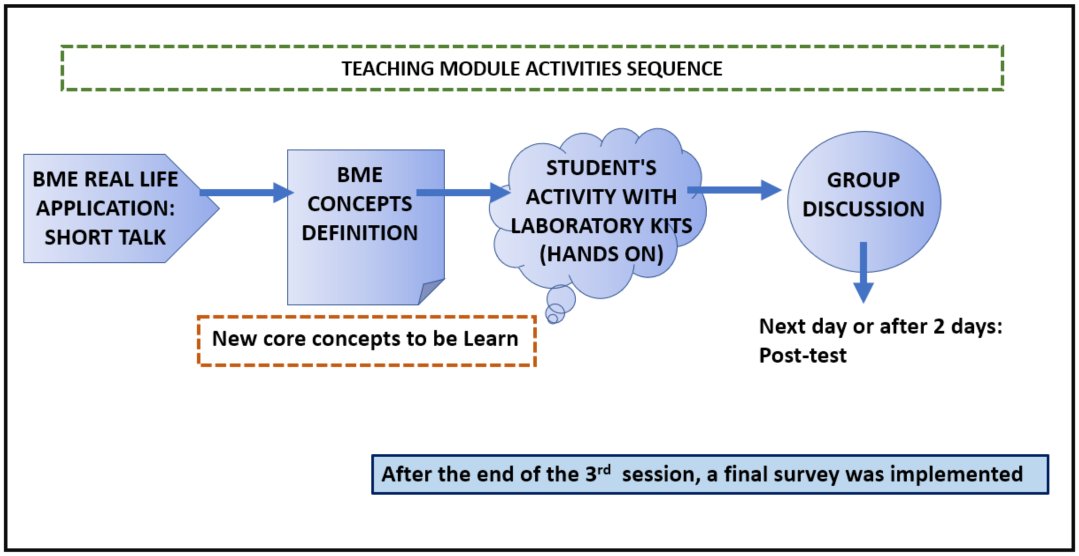

Figure 1. Methodology used as the Teaching Module during hands-on activities

Assessment Method

The module was carried out in a High School in the west of Puerto Rico and was delivered to 11th grade high school students in two groups, corresponding to two different class periods (around 6 to 9 students per group), with each receiving the same module. To evaluate the students on how much they learned and retained from the teaching module, a short test was administered two or three days after each workshop and an overall test (asking for a real-life application) was administered the day after the third test. Each test contained 4 questions based on the hands-on activities and in the afterward discussion. No pre-test was performed, and each test was delivered as a post-test one or two days following each workshop. The questions included inquiries about the student's knowledge such as: the application of the slope equation and understanding of spring constant for elastic materials, cell functions in the body and their importance in human tissues like the human skin, and types of microscopes functioning and their applications. In the overall test, the students identified a human tissue with different compositions of proteins and analyzed its strength depending on the protein content.

Results

The test results are summarized in Table 1. As can be seen, the numbers of students scoring at least 3 questions correct out of 4 questions are as follows: for workshop 1, in group 1, 4 out 6 students, and in group 2, 6 out 6 students; for workshop 2, in groups 1 and 2, 4 out 7 students; for workshop 3, in group 1, 3 out 7 students, and in group 2, 6 out 7 students; and in the overall survey, in group 1, 8 out 9 students, and in group 2, 7 out 9 students. These results suggest that most of the students retained the concepts learned during the activities and were able to apply them to a real BME field application.

Table 1. Results of the short test and overall surveys for the 2 groups.

	Number of Students		Number of students with grades >= 75%		Number of students with grades <75%	
Workshop/Survey Topic	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Microscopes functioning and their applications	6	6	4	6	2	0
Human cells and their functions	7	7	4	4	3	3
Engineering concept: spring constant	7	7	3	6	4	1
Overall Survey-Overview and real-life application	9	9	8	7	1	2

Conclusions and Future Work

Overall, the methodology is shown to be feasible for conceptual retention after 1 or 2 days of hands-on activities for eleventh graders. Some improvements for future workshops are expected to be implemented. These improvements include adding pre-and-post surveys before and after the workshops, improving the concepts during the short talks, and using standards like Next Generation Science Standards (NGSS). Also, the implementation of a control group that does not receive the hands-on activities can be compared with the groups that receive the workshops.

IRB Statement

The facilitator of the sessions (the first author, who is a doctoral student) has the credentials, permission, and training from its academic institution to perform the research and have human subjects and ethics approval, and authorization from the school (informed letter) and students' parents' authorization was requested (consent letter) for the study.

Acknowledgment

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