# Work in Progress: Designing an Introduction to Biomedical Engineering Course Around a Design Challenge

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Introduction

First-Year science and engineering courses which have been modified to incorporate engaging hands-on, team-based projects have witnessed increased retention rates, greater knowledge gains, improved student satisfaction, and increased student enthusiasm over traditional implementations [1,2,3]. Researchers have also concluded that training in Spatial Visualization (SV) is associated with higher retention rates in engineering, especially for women [4]. Spatial Visualization skills refer to one's cognitive ability to mentally manipulate 2-D and 3-D objects. Well-developed Spatial Visualization skills are considered important for success in many STEM fields [5]. A complete restructuring of the 1-credit Introduction to Biomedical Engineering course was completed in the fall of 2017 in order to 1) introduce design thinking, 2) enhance spatial representation skills, and 3) increase comradery among the cohort by having team-based activities throughout the semester. These three objectives have been achieved through the development and implementation of a semester-long design problem with a final build and test. Presented is the process of change and preliminary results after a single offering along with plans for future implementations.

Methods

The freshmen in the Biomedical Engineering program enroll in a 1-credit course during their first semester on campus, BIME 181 Introduction to Biomedical Engineering. The course has a few primary goals:  to introduce students to the field of biomedical engineering, to introduce concepts associated with determining precise problem statements and appropriate solution processes, and to demonstrate concepts in team-based, hands-on activities. In the fall of 2016, the course was structured with three total hands-on activities in 2-hour workshop sections spread throughout the semester and weekly lectures which focused for five weeks on areas of biomedical engineering with the remaining lectures being divided between professionalism, ethics, and curriculum information. A final design project was included but it was entirely theoretical with minimal instruction provided on the design process. The 2016 class included 51 students who attending lecture together but were divided across 3 sections for workshops.

In the fall of 2017, the course was restructured. The lectures were mostly recreated to focus on a semester-long design project, but a handful were maintained to cover professionalism, ethics, and curriculum information. Students attended weekly two-hour workshops instead of 3 per semester which were used to introduce basic lab skills, practice spatial visualization, and work through the design project in a hands-on environment. The project centered on the design of an at-home dialysis machine with the lecture focusing on the entire system. The hands-on activities in workshops focused on improving the dialysis membrane portion of the device to optimize efficiency and reduce cost. The 2017 class included 62 students attending lecture simultaneously, but divided across 3 sections for workshops.

Members of the 2016 cohort were offered but not required to receive any instruction or practice on spatial reasoning, while the 2017 cohort received 4 hours of instruction and practice with half of the instruction occurring before implementation of the skill towards the project.

To establish a baseline from which to evaluate the restructure, voluntary focus groups were administered to the 2016 cohort a year after beginning the course to assess student perceptions of design, teamwork and comradery, and how the course affected their view of the BME curriculum and field. Voluntary focus groups were also administered to the 2017 cohort after all coursework was finished and will be administered again in the fall of 2018 for a 1-year post assessment. To assess the effectiveness of SV training, the Rotations component of the Purdue Spatial Visualization Test – PSVT:R [6] was administered early (as a pre-test) for both the 2016 and 2017 cohorts, but only the 2017 cohort had a post-test at the end of the semester.

Findings

Prior to the restructuring, students provided positive feedback that the course was a platform for group comradery and teamwork skills. However, many students criticized the lack of direction or connection to an engineering process in the course. After the restructuring, students praised the connection between lecturing on the engineering method and the practical, hands-on application of these principles within the course. Students more readily accepted a lack of direction while encountering and working through problems with their teams. Both groups positively reflected on gaining teamwork skills and building relationships with peers. Both groups mentioned SV as a positive experience: fun, helpful, and interesting. Both groups also mentioned thinking about ethics as applied to their projects.

Approximately 84% of the students in the restructured class showed an increase on their individual score with the class average improving from a pre-test score of 71.0% to a post-test score of 83.7%. More importantly, the lowest scoring students who scored below 70% on the pre-test showed the greatest absolute gains with an average increase of 22.4 percentage points. Additionally, the performance gap between the lowest scoring and highest scoring students decreased significantly, from a difference of 22 percentage points on the pre-test to a difference of only 5.6 percentage points on the post-test. A two-tailed t-test indicates that the difference in pre-test mean scores is statistically significant at the 95% confidence level with a p-value of $p<0.0001$. Hence the initial gap between low performers and high performers is statistically significant prior to instruction. Following instructional intervention that included both standard skills training and a semester-long design problem, both groups demonstrated improvements as measured by the post-test. However, the difference in post-test mean scores is not considered statistically significant ($p=0.0658$). Hence, our data demonstrates that the original gap in SV skills has closed to the point where the difference is no longer considered statistically significant between these two groups. Table 2 summarizes these findings and provides normalized gains for each group (absolute gain divided by maximum possible gain).

Table 1.  Summarized feedback from students who participated in BIME 181.  These results are captured from 40 min focus groups which were administered to 1-5 students per group.  Four groups participated in 2016 and three groups in 2017.

| Topic | 2016 cohort prior to course restructure | 2017 cohort after course restructure |
|---|---|---|
| BME Program | -The course kept students interested in their major/field of study<br>-The course helped students feel more involved with their program<br>-The course helped build relationships between peers | -Few comments regarding how the course impacted their opinion of the program<br>-The course helped build relationships between peers |
| BME Career | -The course helped students identify which areas of BME they were/were not interested in<br>-While hearing about faculty research was nice, the course could benefit from talking about career paths/opportunities when entering the workforce | -The course provided a strong introduction to basic engineering concepts<br>-The course activities kept students interested due to their relevance to BME |
| Project – Teamwork | -Students enjoyed random group assignments because it introduced them to new people<br>-Learning how to work in a group and complete a project together was a big takeaway for most students<br>-Students found the collaborative aspect to be a positive experience | -Students related the group project to their future careers as engineers in the BME field<br>-Students learned practical skills to implement in future group projects<br>-Students stressed the benefits of working towards a collective goal with a team |
| Project – Design | -Lack of instruction caused confusion on project goals<br>-Students felt more guidance/stepping stones would have been nice to learn how to accomplish a large goal<br>-Watching other group's presentations helped students see other solutions to the same problem | -Exposure to engineering terminology and techniques was very evident<br>-Students more readily accepted a lack of direction while implementing the design process to overcome challenges<br>-Students enjoyed a project that continued over the semester |

Table 2.  Statistical analysis of the 2017 SV results.

| Students* | Number | Avg. PRE | Avg. POST | Absolute Gain | Normalized Gain |
|---|---|---|---|---|---|
| All | 44 | 71.0% | 83.7% | 12.7 pts. | 0.44 |
| SV-PRE $\leq 70\%$ | 18 | 58.0% | 80.4% | 22.4 pts. | 0.53 |
| SV-PRE $> 70\%$ | 26 | 80.0% | 86.0% | 6.0 pts. | 0.30 |

*Analysis includes only students who took both SV-PRE and SV-POST (44 out of 62 students).

Conclusions and Future Work

Overall, the elements chosen for the restructure proved to be very successful in achieving our original objectives. The semester-long design problem provided great flow through the semester as well as an example application for the engineering and ethics principles discussed in the course. The SV training proved effective with anticipated adjustments for the next offering to continue enhancing the connection of this skill to the design problem. Some improvements will be made to the implementation of the project to ensure design thinking is being taught and applied with minimal distractions.

Following the inspiring SV results, 3 research questions will be explored as the restructure of the course continues to be improved. 1) To what extent, if any, does having an engineering context (design problem) improve Spatial Visualization skills? 2) Can gains in spatial visualization skills be increased through practicing with non-cubic shapes? 3) To what extent, if any, do these approaches help to close the gender gap?

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