Work in Progress: Redesign of Introductory Bioengineering Course to Increase Student Engagement

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Introduction

It has been shown in the literature that at the time of enrollment, about one-third of freshmen intend to pursue STEM as a major in four year institutions.¹ Unfortunately, large portions of undergraduate engineering students who are interested in STEM fields, don't remain engineering majors until graduation with typical retention rates of about 50-60%.¹⁻³ Reasons for leaving are varied, but many complaints point to the “math-science death march,”⁴ i.e., the focus mainly on theory in the early years of most undergraduate engineering programs. Another complaint is the abstractness of the materials presented.

Temple University accepted the initial undergraduate students to the Department of Bioengineering (BioE) in Fall 2013. Amongst the long-term goals of Temple University's BioE department are curricular development and course design/redesign to establish a student-centered learning environment and enhance student engagement, experience, and retention within our new program.

Our program has an introductory course (BIOE 2001) that is used to acquaint students to the broad and varied field of bioengineering. Initially this course designed as a typical ‘survey’ presentation style, where guest lecturers from a variety of backgrounds in BioE would present their research to the class via a lecture-style format. The students were given examinations on the presented material and did group final projects (written and oral portions) on a bioengineering topic of their choice.

However, student feedback indicated that many of the lectures were too “high level,” requiring more foundational knowledge than the students had in order to understand the presented material. The students also indicated that some guest lectures were “boring” and they wanted to “do” more in each area as opposed to just hearing about the material. The instructor commented that the exams required students to regurgitate unrelated facts about different areas of bioengineering with little higher-order thinking needed. This version of the course, as described in the education research literature, was “content-driven” and “teacher centered.”^{5,6}

Our initial efforts for a move towards student-centered curriculum involved a complete redesign of this introductory bioengineering course, BIOE 2001, for Fall 2014.

Methods

Using the principles of integrated course design as described by Fink⁶, we initiated a complete course redesign to incorporate these ideas into the course. (Figure 1)

Figure 1: Modified integrated course design model.⁶

Course Learning Goals:

The first step was to revisit the learning goals for this course. New goals were developed based on Fink’s Taxonomy for Learning, which have been shown in the literature to promote “significant student learning.” The taxonomy is based on six areas that should be taken into consideration when developing course goals: foundational knowledge, application, integration, human dimension, caring, and learning how to learn.⁶

A consideration for our department was that we have several “pathways” or plans of study within bioengineering, such as biomaterials, biomechanics, tissue engineering, etc. This introductory BioE course needed to support the educational desires of all bioengineering students as well as help those students that were “undecided” or unsure as to which pathway best fit their longer-term career goals.

With the redesign, the new goals for BIOE 2001 are: “At the end of the course, students will...

- I. Be more interested in the bioengineering field so that they can choose a pathway of interest for further study during their undergraduate career.
 - Fink’s Taxonomy: Caring, Human dimension
- II. Analyze current real world problems related to bioengineering by assessing resources available and brainstorming possible solutions to these problems.
 - Fink’s Taxonomy: Application, Integration, Learning how to learn

These significant learning course goals are closely tied to the ABET student outcomes assigned to this course:

- F) An understanding of professional and ethical responsibility

G) An ability to communicate effectively

J) Knowledge of contemporary issues

Feedback and Assessment:

Several assignments were used throughout the semester to assess students' attainment of the newly developed course learning goals.

- 1) Final group project, which included a written report and group presentation. Note: The final group project was the only part unchanged in the course both before and after the redesign. This assignment was used to assess Course Goals I and II.
 - a. For the final project, students selected topics on global health issues or other problems in bioengineering. The students were asked to brainstorm and design solutions to these bioengineering issues.
 - b. The project was scaffolded, where parts were turned in throughout the semester for instructor feedback prior to submission of entire written report and oral group presentation.
- 2) Response Papers were 1-page reports answering prompted questions based on readings of scientific reviews and primary scientific literature, popular science literature, videos, or podcasts on the topics of bioengineering. These assignments were used to assess Course Goal II.
 - a. Students were exposed to other points of view on bioengineering outside of those presented by guest lecturers. They wrote weekly papers reflecting on how these topics can affect them and society.
 - b. The materials were provided asynchronously via the course learning management system.
 - c. Examples of Response Paper prompts were: 1) Should the government regulate behavioral economic marketing strategies? (Presented after review of materials on neuromarketing), or 2) What are the issues that need to be dealt with when considering design and use of biomaterials in the body? What are the potential limitations? Any ethical implications? (Presented after review of materials on biomaterials)
- 3) Self-assessment on pathway of interest within BioE. This assignment was used to assess Course Goal I.
 - a. Students were asked about their choice of pathways of interest at the start and end of the semester to see if the course influenced student choices.

Teaching and Learning Activities:

As described by Fink⁶, materials that are assessed in class should follow opportunities for the students to practice these skills.

- 1) *Guest Lecturers*: The guest lecturers presented real world problems in their areas of bioengineering, such as stem cell use, design of orthopaedic implants, and development of engineered whole organs. As part of the class, students tackle the presented problems in group discussions with facilitation by guest lecturer and instructor. Guests also describe needed relevant undergraduate courses for people interested in that particular field of study. Note: Although guest lecturers were used prior to the redesign, the presentations by the guest lecturers changed to include issues addressed by bioengineers and discussion of didactic course work needed for that field.
 - a. These in-class group exercises encourage student engagement with the material presented by the guest lecturer.
 - b. Students also get exposed to real world problems and potential solutions, which will be useful when the student work on their final projects.
 - c. Examples of guest lecturer problems presented were 1) How to create a tissue engineered heart (presented in Tissue Engineering Lecture) or 2) What affect does the kangaroo tail have in hopping motion? (presented in the Biomechanics Lecture)
- 2) *Mini-Lectures*: Students performed group presentations based on materials from that week's topic of interest. Each group did 2 presentations during the semester to help them practice presenting orally and handling questions.
- 3) *In-class group discussions*: Using the week's topic of interest, such as biomechanics, a problem or issue was presented to students, who discuss, in their groups, possible solutions. The students report out the group's conclusions and turn in a short write up on discussion.
 - a. Examples in-class discussion questions were: 1) What potential solutions can you provide that would permanently control a neighborhood feral cat population that would not include current methods of trap and neuter or systematic killing of the animals? (presented after a guest lecture on drug delivery methods) or 2) Bioprinting of organs - Are we there yet or is it total hype? (presented after a guest lectures on tissue and regenerative engineering).

Data Analysis

Assessment of redesign of the BIOE 2001 course was based on an on-line survey (see Appendix for questions asked) given to all past student participants in the course. The subjects were asked to answer a series of questions based on their experience in BIOE 2001. This survey included questions such as, the benefits of the asynchronous course materials, the students' sense of value with respect to the guest lecturers, and the achievement of course goals.

The survey questions were based on a 5-point Likert scale, where 1 – strongly disagree and 5 – strongly agree with 3 – neutral. There were also open-ended questions for students to respond to about potential points of improvement for the course. Simple data analysis techniques (mean, standard deviation, percentage response) were utilized to analyze the survey responses. The

differences in the responses between the two cohorts was determined using a t-test with unequal variances with a significance level set to $\alpha = 0.05$.

Results

61 students have participated in the BIOE 2001 course since its inception in the new bioengineering program, where the Fall 2013 cohort (prior to redesign) had 18 students and the Fall 2014 cohort (after redesign) had 43 students in two sections. The enrolled students were mainly declared bioengineering students, but the course was not restricted to this major only. Each cohort had approximately 5% of non-major students. There are currently no pre-requisites for the course and students typically take the course in their 2nd or 3rd semester. To date, a total of 10 students (16.4%) responded to the survey, where 4 were from Fall 2013 cohort (3 male and 1 female students) and 6 were from the Fall 2014 cohort (2 male, 3 female, and 1 “chose not to answer” students).

For the closed response questions (Figure 2), the students in both cohorts were asked (see Appendix for full survey questions) about the influence of BIOE 2001 on their choice of pathway to study, desire to obtain a graduate/post- baccalaureate degree, etc. For the most part, the Fall 2013 cohort reported a greater positive influence of BIOE 2001 based on all questions. In contrast, the Fall 2014 stated that the course increased motivation to study chemistry and to continue on to post- baccalaureate degrees. However no significant differences in student responses based on cohort were found.

Figure 2: Student responses (average $\pm$ standard deviation) to each survey question (described briefly in figure) for student cohort prior to course redesign (Fall 2013) and after course redesign (Fall 2014). See Appendix for entire question asked in survey. There were no significant differences found between the two cohorts based on current data. 5-point Likert scale was described as 1 – strongly disagree and 5 – strongly agree with 3 – neutral.

Two open ended survey questions were included in the survey based on the most and least helpful parts of the course in preparation for future careers in bioengineering. This survey information was combined with comments on student course evaluations and oral responses to the instructor questions about student opinions of the course. Prior to the redesign, the students stated that they found the final project to be most helpful and the guest lecture presentations were least helpful. After the redesign for the Fall 2014 cohort, students responded that they found most helpful the final project, guest lectures, asynchronous materials, and “researching and writing about news articles,” which was based on the weekly response papers. The least helpful part of the course was extensive writing in the weekly response papers for a 2 credit course.

Discussions with the instructors of the redesigned course indicated that they found the students very engaged in group work and there were many lively debates in the class. The instructors found that the quality of the response papers and oral presentations via the “mini-lectures” improved over the course of the semester. In addition, the final reports and presentations were overall of higher quality as compared with the Fall 2013 cohort.

Discussion

Initial feedback for the redesign from students and instructors was positive. Students were very engaged with in-class group work and stated that they enjoyed learning from the guest lecturers. The Mini-Lectures enabled the students to practice, give and receive feedback about their presentation skills, which helped improve final project oral presentations over the previous 2013 class. Using the Response Papers with question prompts, ensured that the students reviewed the material and encouraged them to reflect on the material personally and during in-class group discussions. Many students also took the opportunity of the mini-lectures and response papers to research further into weekly topics and bring these insights and findings to share with the class.

Although there were no significant differences found from the survey responses between the two cohorts, the response rate to date was very low. Future use of the survey would be to include it prior to the end of the semester and offering some nominal extra credit to hopefully boost the response rate.

As the class increases in size each year, future courses may replace some of the weekly response papers with quizzes (multiple choice and short answer questions) on the asynchronous material to reduce the cumbersome grading load, but ensuring that students review the material each week. In addition, further faculty development and training on how to facilitate class group discussions to assist the guest lecturers in developing a student centered environment.

The redesign of BIOE 2001 used research-based methods to reinvent a typical introductory survey course in effort to encourage greater student engagement within the class. The use of integrated course design methods helped the instructors build a class that connected the desired student long-term, education goals with class activities and assessments. Based on instructor observations, the dynamic of the course changed dramatically between the two cohorts from passive listening of class-long lectures to active group work and discussion of topics.

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Appendix

Survey Statement
After taking this course, I see a connection between global health issues and efforts in the bioengineering field to address these issues.
I believe that I need bioengineering degree to work on addressing current global health issues.
After taking this course, I see connections between theoretical engineering concepts and how they are applied in real world situations.
This course has increased my motivation to study math.
Taking this course has increased my desire to obtain an undergraduate bioengineering degree.
Taking this course has increased my desire to obtain a graduate bioengineering or other post-baccalaureate degree.
This course has increased my motivation to study chemistry.
This course has increased my appreciation of the depth and interconnectivity of the bioengineering field.
This course helped me decide on the plan of study (pathway) that I will follow during my undergraduate career.
I felt that the guest lecturers in the course influenced my choice of pathway within the bioengineering program.
I felt that the guest lecturers in the course increased my appreciation for the field of bioengineering.

I felt that the materials (videos, articles, lecture slides, etc.) used in the course influenced my choice of pathway within the bioengineering program.

I felt that the materials (videos, articles, lecture slides, etc.) used in the course increased my appreciation for the field of bioengineering.