Patient Centered Design in Undergraduate Biomedical Engineering

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Abstract

Design in engineering is not only a core competency for students but is also a useful framework for collaborating across the university. In particular, contextualized patient-centered design based upon immersion and deep empathy are increasingly important skills for graduates planning to work in industry in biomedical design and innovation. At the University of Virginia we offer an advanced design elective in Biomedical Engineering in which students focus on observation and needs identification, followed by the development of initial concepts and prototypes. For the past two years, we taught two different versions of the course: a spring semester clinic-focused offering in which students identified needs based on immersion within one of the divisions of our academic medical center, and an accelerated “January term” patient-focused version in which student teams worked directly with specific patients and their healthcare teams to identify needs and develop concepts. The primary learning objective for this course, regardless of the version (i.e. clinic-focused vs. patient-focused), was to place a strong emphasis on context driven design, inter-professional collaboration, and developing deep empathy.

In the patient-focused January term version of the course, participating patients exhibited a variety of chronic conditions (visual impairment, diabetes, immunogenic disorders, etc.). Students developed a deep understanding of each patient’s health background, visited their patient’s home, and collaborated with professional healthcare providers managing care for these patients, including doctors, nurses, pharmacists, occupational therapists, visual impairment educators, and social workers. In the clinic-focused spring version, students spent at least 10 hours shadowing in clinics and interviewing doctors, nurses, and technicians. In both versions, students were provided with training on interviewing, observation, and notetaking, as well as HIPAA privacy training. Once students articulated a design need statement, they developed rudimentary prototypes to present to their patient or medical teams, depending on the version of the course. Inevitably, students had to iterate their designs multiple times in response to feedback from patients and caregivers. Final designs ranged from physical products and devices to software applications.

The ABET course objectives and assessments were virtually identical between the two versions of the course. In 2016 all 18 of the students in the patient-focused version met at least two of the three objectives, and 83.3% met all three objectives. However, in the spring clinic-focused version of the class, only 57% of 21 students met all three objectives, and 5 students met only one or none of the objectives. Additionally, course evaluations for the January term version were higher than the spring version (4.76 vs. 3.78 course mean on a 5-point Likert scale). We believe the improved results for the January term course may be due to one or more of the following factors: 1) the focus on specific patients—and resulting increase in empathy and motivation—rather than a more impersonal clinical observation, 2) the diversity of majors present in the January term course (only half were biomedical engineering majors), and 3) the intensely focused timeline of the course (two weeks vs. a full semester). Anonymous student feedback provides anecdotal support for #1 and #3 above, although all three are likely contributors. We conclude that a focused and in-depth interaction with specific patients yields improved design outcomes and increased student satisfaction with the experience.
Introduction

The knowledge and practice of engineering design is a core competency required of all ABET-accredited undergraduate biomedical engineering programs, as per Criterion 3, Program Outcome c [1]. Towards developing the necessary design competency, biomedical engineering (BME) majors at the University of Virginia are required to complete a one-semester sophomore-level skills-based course covering practical aspects of the design process, including iterative brainstorming, hands-on prototyping & fabrication, CAD, materials, machining, assembly, and basic microcontroller design. Seniors then complete a yearlong capstone sequence in which they pursue a client-mentored project and apply the skills they have developed in the prior courses within the curriculum [2]. All projects in the introductory design skills course and the vast majority of projects in the capstone are client-sponsored, pre-identified problems or need areas that the client pitched to potential teams, such that students who take these core design courses typically do not have the opportunity to identify clinical or patient-centered needs as part of the course structure. However, a growing number of our undergraduates are interested in pursuing industry careers in design and innovation and would benefit from open-ended context driven design experience in medicine that fosters observation skills, deep empathy, and needs-finding. These contextual skills have been found lacking among engineering graduates by nearly half of respondents in a survey of 1,622 employers [3]. A contextualized learning approach [4-5] in engineering education has been shown to improve student motivation, confidence, and conceptual understanding in a variety of studies [e.g. 6-7].

To meet this “design gap” in our curriculum and to address the need for human-centered contextualized design experience for our students, we developed an upper-level elective course entitled “Design & Innovation in Medicine,” which focused on open-ended needs identification and the development of initial concepts and prototypes. The prerequisites for this elective include the sophomore-level introductory design course or instructor permission. For the past two years, we taught two different versions of this elective: a spring semester clinic-focused offering in which students identified needs based on immersion within one of the divisions of our academic medical center, and an accelerated two-week “January term” patient-focused version in which student teams worked directly with specific patients and their healthcare teams to identify needs and develop concepts. The key deliverables and course objectives and assessments were identical for both versions of the course within each respective year (see below), allowing us to conduct a comparative study between the two formats in 2016 and 2017. In both versions, students were provided with training on interviewing, observation, and notetaking, as well as HIPAA privacy training. Once students articulated a design need statement, they developed rudimentary prototypes to present to their patient or medical teams, depending on the version of the course. Most students had to iterate their concepts multiple times in response to feedback from patients and caregivers, and final designs ranged from physical products and devices to software applications.

Undergraduate biomedical engineering courses that involve clinical immersion are not unique in BME education and have been developed at a number of universities (see, for example, [8]-[10]). Other programs have developed patient-focused design courses, typically under the broad umbrella of rehabilitation engineering or design for patients with disabilities [11]-[12]. However, we are not aware of any published studies of existing courses in human-centered design and
needs finding that contain otherwise identical sections that focus on either clinical immersion or patient interaction, nor are we aware of a comparison of student outcomes resulting from a semester-long vs. an accelerated two-week design course. The Design & Innovation in Medicine course at our institution thus provides an opportunity to assess the coupled impact of immersion type (clinical observation vs. patient shadowing) and course format (intensive short-term course vs. semester-long) on the quality of needs-finding. We hypothesized that extensive time with a specific patient during the short-term course would yield deeper empathy from the students and thus lead to higher quality needs and initial concepts, but that the longer timeframe of the semester would yield higher quality final prototypes due to the considerably longer time available for iteration and client feedback. More broadly, we sought to compare the course outcomes in the accelerated January term (J-Term) version of the course to those of the full semester to ascertain whether the shorter format was feasible pedagogically as a means of training students in context-driven, human-centered design and patient/clinical needs-finding.

Course Objectives and Assessments

Both versions of the course have the same three overarching objectives:

1. Students work in teams and are guided through the process of problem identification, needs determination, development of product specifications and realistic constraints, brainstorming, concept selection, and prototyping of a medical product.

2. Students learn about topics important for biomedical product design and development, including articulating design need/intent, understanding clinical need through shadowing, using principles of human centered design, collecting and analyzing data to assess design interventions, developing visualization through CAD skills, regulatory constraints, business models, and healthcare reimbursement, and they apply this knowledge in the context of medical product design.

3. Introduce students to the process of communicating a design process and outcomes by participating in multiple design critique sessions and by developing and submitting a final video presentation.

Formative assessment was used throughout the course to help students understand their own progress as they developed their designs, determined feasibility, and communicated their designs in multiple in-class workshops and design critique sessions. Summative assessment in the 2016 J-Term and spring semester consisted of the following:

- **Class participation and blog**: Students were evaluated by the instructors throughout the semester on their engagement in and contribution to class discussions, as well as a series of blog entries in which they shared their discoveries, insights, and points of view as they progressed through the three class projects.

- **Personal health project**, in which students were paired with a classmate and sought to address one area of health for their partner by interviewing, gaining empathy, developing a journey map, tracking data and quantifying findings, designing an intervention, and testing the impact of the intervention through further data tracking and analysis. This project, presented orally at a design critique review session, was evaluated on 5
components: partner engagement and empathy, journey map, intervention, meaningful & visual data, and quality of the oral presentation.

- **Reverse-engineering project** involving analysis and CAD of an existing medical product. This written assignment was evaluated specifically in 5 sub-components: FDA regulatory analysis, clinical use, organization/clarity, quality/details/materials analysis, and CAD dimensions and orthographic representations.

- **Patient/medical center project**, in which students were required to engage in patient or clinical shadowing (depending on the version), develop needs statements, develop product specifications and realistic constraints, brainstorm solutions, select & prototype concepts, and gather patient/clinical feedback on proposed solutions. Students presented their need, design process, and proposed solution in a video format. Experienced faculty, clinicians, local entrepreneurs, and design faculty from the School of Engineering and Applied Sciences and from the School of Architecture were available to question the students about their ideas in an organic and realistic manner in the Q&A following the video presentation. Students were evaluated on 1) the quality and level of accomplishment in their designs, and 2) the quality of the video presentation and communication of the process and outcomes.

Assessments in 2017 (both J-Term and spring) were nearly identical to the 2016 assessments listed above, with the exception of the personal health project and blog, which were removed in response to student feedback from the previous version of the course.

**Clinical Immersion Spring Semester Version of the Course**

The Spring Semester clinic-focused version of the course involved 10 hours of clinical observation by the students. Over the past two years we partnered with Pediatrics and Orthopedic Surgery. The clinical observation component requires permission forms signed by our clinical sponsors, up-to-date vaccination forms, legal documentation covering students in the clinic, proper ID badges, and coordinating tight schedules for clinical teams with busy undergrad students. Overall our students have accumulated over 900 hours of clinical time, which to our knowledge is an unprecedented figure for non-clinical courses.

Location for observations varied from inpatient floors, where students rounded with the clinical teams, to outpatient clinics, where students observed patient assessments, to procedural cases. For Pediatrics, the majority of time was spent inpatient, in the PICU and NICU; whereas Orthopedics the observation time was primarily outpatient with some inpatient service. The nature of observations influenced the types of projects generated. In 2017 we partnered with Orthopedics, where most time was spent in outpatient clinics. As a result, at least 3 patient compliance and patient follow-up projects were generated by the BME students. In Pediatrics in 2016, projects biased toward tools for inpatient pediatrics care like respiratory support or patient comfort in long-term stay units.

**Patient-Focused January Term Version of the Course**

In the patient-focused accelerated January term version of the course, the extremely short timeframe of the course (~2 weeks) rendered it infeasible to immerse students in the clinic for
prolonged period of time. Because the J-Term is such an intense, focused period, we chose focus
the clinical immersion into partnering with specific patients in the local community (with a ratio
of approximately 5-6 students per patient). Participating patients exhibited a variety of chronic
conditions (visual impairment, diabetes, immunogenic disorders, etc.). Students developed a
deep understanding of each patient’s health background, visited their patient’s home, participated
in daily activities with the patient (e.g. going to the gym, walking the patient’s dog, etc.), and
collaborated with professional healthcare providers managing care for these patients, including
doctors, nurses, pharmacists, occupational therapists, visual impairment educators, and social
workers.

Example patient projects from the 2016 and 2017 J-Term students include: developing an
accelerometer-based sensor for detecting the frequency of tremors as a noninvasive proxy for
low blood glucose in a patient with Type I diabetes (using a Raspberry Pi attached to the wrist), a
sensor system with auditory alerts for a visually impaired patient to be able to swim while
remaining in her side of the lanes while sharing the lane with another swimmer, and a braille-
enabled pill sorting case to assist a visually-impaired type-II diabetic with Devic’s syndrome
(similar to multiple sclerosis) manage her 12+ daily medications, among others.

Instructional differences between the two sections

While the assessments in both the J-Term and spring versions of the course were identical within
a given year, the primary mode of instruction was necessarily different due to the divergent
timescales and scope of the projects. In the J-Term course, most of the class time was set aside as
studio time for the students to work on their needs, concepts, and prototyping with hands-on
instructor guidance and formative feedback throughout. In the spring, in-class time was primarily
didactic and discussion-driven, with students performing most of the work on brainstorming,
prototyping, and testing outside of scheduled class time. Having patients readily accessible to
the J-Term students allowed for rapid feedback so that the students could quickly iterate their
concepts, whereas the iteration in the spring version was slower due to the comparatively larger
number of stakeholders (multiple physicians, nurses, physical therapists, etc.). Students gained
more experience in integrating the opinions of stakeholders in the spring relative to the shorter J-
Term version of the course.

Results

Overview of Study and Course Outcomes

Our key research question for each of the two versions of the course—winter term (“J-Term”)
patient-focused vs. spring semester clinic-focused—was as follows: Overall, did students in both
versions meet the course objectives (i.e. is the compressed format feasible for achieving the
desired learning outcomes)? In addition to comparing assessments of student performance, we
also assessed student opinion of the course through anonymous end-of-course evaluations.

In 2016, a combined 39 students were enrolled in both versions of the course (18 in J-Term and
21 in spring), and in 2017, a combined 35 students were enrolled (15 J-Term and 20 spring).
Nearly 75% of all 74 students were BME majors, and 61% were juniors. Approximately 11% of the students were graduate students. Since the graduate students were enrolled under a different course number, they were required to complete additional assignments that were assessed as part of their grade to ensure the course met graduate-level standards. These graduate assessments were not included as part of the analysis in this study, and all other assessments for the grad students were identical to those of the undergraduates. Table 1 below summarizes data on student year and major in each of the four course offerings. In both years, the J-Term students represented a more diverse set of majors (not just BME, but also electrical engineering, mechanical engineering, civil engineering, computer engineering, computer science, engineering science, and systems engineering (Table 1).

Table 1: Academic level and major of students in each course section.

<table>
<thead>
<tr>
<th>Academic Term</th>
<th>Total # of Students</th>
<th>Soph.</th>
<th>Junior</th>
<th>Senior</th>
<th>Grad</th>
<th>BME</th>
<th>EE/CpE</th>
<th>MAE/CE</th>
<th>Systems</th>
<th>CS</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>J-Term 2016</td>
<td>18</td>
<td>3</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>11</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2016</td>
<td>21</td>
<td>20</td>
<td>1</td>
<td></td>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J-Term 2017</td>
<td>15</td>
<td>1</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Spring 2017</td>
<td>20</td>
<td>9</td>
<td>7</td>
<td>4</td>
<td></td>
<td>16</td>
<td>2</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To assess the course objectives (see previous section), specific sub-components of the assessments were tallied and averaged, with a grade of mid-B or better considered as the threshold for meeting the objective. Course Objective #1 (needs identification and execution of the design) was assessed by averaging the accomplishment/design quality component of the patient/clinical project, and the designed intervention component of the personal health project (2016 only). Course Objective #2 was assessed by the participation score (including instructor evaluation of in-class discussion and participation in the relevant topics), the reverse engineering project (all components except the organization / clarity component), and three of the components of the personal health project in 2016 (partner engagement & empathy, journey map, and collection/analysis of meaningful data). Course Objective 3 was assessed by performance on the organization/clarity component of the reverse engineering project, the quality of the oral presentation component of the personal health project (2016 only), and the quality of the end-of-term video presentation for the patient/clinical project. Table 2 summarizes the percentage of students in each class who met each of the course objectives.

Table 2: Percentage of students who met the three course objectives each term.

<table>
<thead>
<tr>
<th>Academic Term</th>
<th>Course Objective</th>
<th>Met all 3 objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#1</td>
<td>#2</td>
</tr>
<tr>
<td>J-Term 2016</td>
<td>94%</td>
<td>100%</td>
</tr>
<tr>
<td>Spring 2016</td>
<td>81%</td>
<td>71%</td>
</tr>
<tr>
<td>J-Term 2017</td>
<td>87%</td>
<td>100%</td>
</tr>
<tr>
<td>Spring 2017</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Overall, there was not a significant difference (unpaired t-test p < 0.05) between the J-Term and Spring performance in terms of quantitative performance toward meeting each of the course objectives. In 2016, however, only 57% of students in the spring course met all three objectives (and 5 students met only one or none of the objectives), whereas 83% of students in the J-Term course met all three objectives. While this result falls just short of statistical significance for a
threshold of $\alpha = 0.05$ (Barnard’s test $p = 0.083$), it suggests a pedagogical deficiency in some aspect(s) of the Spring 2016 course (see Discussion).

**Analysis of Student Course Evaluations and Comments**

At the end of each term, students completed anonymous course evaluations answering multiple questions relating to the course and to the instructor. We have analyzed the key course-specific metrics common to the evaluations in both the J-Term and spring versions of the course, and we have summarized some representative student comments from each of the terms. Quantitative responses were based on a 5-point Likert response (5 = strongly agree, 3 = neutral, and 1 = strongly disagree) to the following statements: “I learned a great deal in this course,” and “Overall, this was a worthwhile course” (Table 3). Mean responses reflect a weighted average based upon the number of students assigning a specific score, and standard deviations were calculated according to the same weights.

**Table 3**: Summary of anonymous end-of-course feedback for each term (5-point Likert scale).

<table>
<thead>
<tr>
<th>Academic Term</th>
<th>Percent completing evals</th>
<th>Learned a great deal Mean</th>
<th>SD</th>
<th>Overall worthwhile Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>J-Term 2016</td>
<td>94.4%</td>
<td>4.76</td>
<td>0.44</td>
<td>4.76</td>
<td>0.44</td>
</tr>
<tr>
<td>Spring 2016</td>
<td>100.0%</td>
<td>4.00</td>
<td>0.65</td>
<td>3.95</td>
<td>0.94</td>
</tr>
<tr>
<td>J-Term 2017</td>
<td>73.3%</td>
<td>4.82</td>
<td>0.40</td>
<td>4.82</td>
<td>0.40</td>
</tr>
<tr>
<td>Spring 2017</td>
<td>75.0%</td>
<td>4.31</td>
<td>0.86</td>
<td>4.62</td>
<td>0.65</td>
</tr>
</tbody>
</table>

The quantitative weighted averages of the responses to whether the students learned a great deal in the course and whether they found it worthwhile were analyzed using a one-way ANOVA, followed by Tukey’s multiple comparisons test. For the responses to “I learned a great deal,” significant differences in means ($p < 0.05$) were found between two pairs of terms: 1) J-Term 2016 and Spring 2016 ($p = 0.002$), and 2) Spring 2016 and J-Term 2017 ($p = 0.004$). In both cases, the evaluations for Spring 2016 were lower than the two J-Terms. (Spring 2017 was not found to be different from any of the other sections.) Similarly, for “Overall this is a worthwhile course,” significant differences in means were found between the same two pairs above (J-Term/Spring 2016, $p = 0.0036$, and Spring 2016/J-Term 2017, $p = 0.0066$), as well as between Spring 2016 and Spring 2017 ($p = 0.040$).

These quantitative results are consistent with some of the free responses student comments provided on the evaluations.

**J-Term 2016**:
- “I very much enjoyed this course. The patient health project was very interesting and fun, but it also demanded a lot of my time and attention. Sort of in the same boat, the personal health project, in my mind, was not a worthwhile experience for me. I found it very hard to get any actual useful data for this project, and I constantly felt it taking the back seat in my priorities to the patient project.”
- “This course is awesome and is unique in that it offers something different from the ordinary course offered during the semester term. It was very cool to experience human-centered design with real patients. This course should definitely be offered again, with
maybe some structural changes. The [personal health project] was not the best, in my opinion. I felt like I didn't get as much out of it than I could have. It felt very forced, and in the end I didn't feel like we accomplished our goals.”

**Spring 2016:**
- “Overall I enjoyed the course and learned much more than I expected to about design. However the course felt disorganized and changed directions quite a lot. I think the course should either be focused on what was done in the beginning of the course (PHP, Observations, Need Statements, Empathy, and beginning Developing an idea) or towards the end (iterations, ideas, prototypes, feedback, etc.). I just didn't feel we had enough time to make actual prototypes or iterations and don't think it's ‘fair’ to grade based on prototypes when the course seems to be much more focused on the thought process of design.”
- “I really like the clinical visits and the guest speakers we had, but overall this class seemed pretty disorganized. It was supposed to [be] more design based but in reality we spent over a month and half on the personal health projects trying to learn to be empathetic which I personally believe would have had the same benefit if we did them in two weeks max. I suggest limiting the timeframe of them or getting rid of the PHP all together. The class seemed unorganized where the syllabus was constantly changing every other day as well. The group exercises at the beginning of class while entertaining sometimes were a waste of time most of the time as I did not learn anything substantial from them.”

**J-Term 2017:**
- “I really like the course; and in fact I loved the way it was in a small class setting. … [T]his was the only class I took in which I interacted with every person and knew their names too. It made me feel loved. I liked the way that engineering and creativity/art were both valued in this course. Too often, students take a technical approach only but as told in class, people are not rational (all the time). Other factors need to be taken into account. That is why we met with patients and got to see how they feel. If anything, I gained a lot of empathy for disabled people.”
- “Absolutely an amazing class! I’m really glad I had the opportunity to take it as a JTerm. It was really intense and we put in a lot of hours creating our prototypes and final videos but for a JTerm it was doable because I had no other responsibilities.”

**Spring 2017:**
- “This has been my favorite BME class I have taken at UVA. It is the first class that we got to apply what we have learned in all our other BME classes to real world problems. I loved that we got to shadow and get hands on experience with orthopedics. The guest lectures were also very informative. The final project is great because we get to be creative and help solve a problem that we saw during shadowing. Overall, I loved the class!”
- “I thought this course was pretty cool and a nice change of pace from a typical classroom setting. I think the primary critique I have would having a clearer end-goal in mind when we begin our final projects. I think many of us were unsure of how abstract it was and did not know how to even start tackling the project. Also, I wish we would have had more
time to really delve into the final projects as I thought that was mostly the basis of the class. However, all things considered, it was still very fun.”

In general, the Spring 2016 version of the course received the most critical feedback, both quantitatively (Table 3) and in the free response comments. Interestingly, the longer full-semester timeframe seems to have led many of the students to feel that they were less focused and lost at times as they progressed through the course and worked on their projects. This lack of focus and uncertainty about deliverables was not an issue in either J-Term version due to the absolute necessity of forcing the students to focus very early on (by day 3 or 4 out of 10). For the Spring 2017 course, we implemented more guided in-class workshops to help the students process the information they received from the clinic, and we provided cleared expectations for what milestones the students should be at throughout the semester. Additionally, the clinics within Orthopedics in Spring 2017 were more similar procedurally and in how they were managed than those within Pediatrics in 2016 (e.g. NICU vs. developmental pediatrics clinics), perhaps leading to more diffuse observation experiences for the students and overwhelming them with the breadth of problems the field.

Most of the positive comments about the course from each of the terms mentioned the “real-world” nature of the projects and the immersion into the clinic or interaction with the patients. While we did not conduct quantitative assessments of empathy, the students who specifically mentioned that they developed empathy were ones who took the J-Term version of the class (e.g. see first comment under J-Term 2017 above), whereas none mentioned empathy in the clinic-focused semester versions. The students who took the spring versions responded positively to the clinical exposure and the interaction with physicians, nurses, and other caregivers.

Discussion

The positive course outcomes from two years of a short term (J-Term) and a semester-long design class suggest that an accelerated short-term format is at least as effective at training students in context-driven clinical design and needs-finding as a full semester format. While the scope of the projects and mode of instruction were very different between the two versions of the course, the outcomes were comparably positive. An initial concern we had in teaching the J-Term course was that the compressed timeline would preclude meaningful design iteration in response to client feedback. However, due to the availability of patients and almost daily (or more frequent) back-and-forth between the teams and their assigned patient, iteration on needs and concepts occurred almost to a greater degree than during the semester versions of the course. Interestingly, the course with the poorest student outcomes was also the course with the worst student evaluations (Spring 2016). We believe that there are a number of factors that led to the problems with that iteration of the course, including too little guidance in focusing the students in a broad clinical area and setting concrete milestones and deliverables throughout the semester. Additionally, the personal health project that we implemented in 2016 was generally not well received by the students, as most of them failed to see the applicability to their clinical projects.

A somewhat surprising finding was that the complexity of many of the final prototypes was similar between the two versions (with a few notable exceptions). We believe that the truly
multidisciplinary nature of the students in the J-Term version, in which barely over half the students were BME majors, led to an integration of skills that ultimately yielded higher quality deliverables. In the future, we will attempt to more deliberately recruit non-BME majors into the spring semester version of the course, since diversity of skills on multidisciplinary teams is known to result in improved designs [13].

In future iterations of the course, we will attempt to determine whether immersion in a specific patient’s life is the critical variable determining success of the short-term course, or whether the compressed and highly focused nature of the observation/immersion is the greater predictor. To test this variable, we modified the most recent J-Term version (2018) to include clinical immersion at a large non-academic hospital in a metropolitan area, focusing specifically on surgery and clinical simulation and training, rather than the patient-centered approach from the previous two years. Initial feedback from the students seems highly positive, and going forward we will quantitatively assess the impact of a highly focused clinical immersion within a short-term course on student outcomes. Based on our initial experiences in early 2018, the quality of needs assessment appears to have improved, although less actual prototyping and testing was possible simply due to time limitations. Future work will help us ascertain what factors lead to better student outcomes in the hope that we can apply those findings to the semester-long version of the course. Since our sample size for this elective will continue to be relatively small, we plan to supplement the quantitative surveys described in the present study with qualitative data based upon a thematic analysis of focus groups of students who have taken the courses.

In conclusion, we believe the highly positive results for the accelerated January term course may be due to one or more of the following factors: 1) the focus on specific patients—and resulting increase in empathy and motivation—rather than a more impersonal clinical observation, 2) the diversity of majors present in the January term course (only half were biomedical engineering majors) resulting in truly multidisciplinary teams, and 3) the intensely focused timeline of the course (two weeks vs. a full semester) empowering students to accomplish more due to limited distractions. Anonymous student feedback provides anecdotal support for #1 and #3 above, although all three are likely contributors. We conclude that a focused and in-depth interaction with specific patients yields at least as good design outcomes and student satisfaction with the experience as a semester-long version of the course.

References