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Assessment and Impact of a Clinical Observations and Needs Finding Course on Biomedical Engineering Education Outcomes

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Abstract

In the field of biomedical engineering, needs identification and solution development are an important element of the design process. In our undergraduate curriculum, a course was designed to allow clinical observation and provide an opportunity for students to learn about engineering design and engage with clinicians via completing rotations in medical facilities near our campus. While this type of course is not unique, evaluating its efficacy is not simple. Given the broad range of institutional resources available- such as proximity to a medical school, or residency programs- reporting the quality of such courses within the context of such available resources is of broad interest to the engineering community. This study sought to measure the effectiveness of a junior-level clinical observations course designed for a major land-grant, public university without proximity to a medical school. We compared IP generation and pre- and post-class surveys were used to quantify students' self-efficacy, motivations, and ability to make connections to real-world problems. The total number of IP applications increased more than two-fold following the adoption of the course, and survey results indicated students' collective improving understanding of the design process and increased confidence in engineering-related skills. This study included a sample size of 75 undergraduate students. NVivo, a qualitative data analysis software, was used to analyze the open-response survey questions. NVivo requires an input of qualitative data that can be coded to produce a quantitative response, decreasing the chance of cherry-picking and researcher bias in data analysis. Such software allowed for the manual and automatic coding of themes identifiable in the data. Sentiment analysis was performed to analyze the frequency and tone of word usage. Ongoing work will continue to examine the long-term impacts of the course concerning the above metrics as well as student retention and graduate placement.

Introduction

Myriad undergraduate Biomedical Engineering programs have developed programs that seek to provide an element of "clinical immersion" for students to learn about real-world problems that can be solved by engineering design [1] – [5]. These programs are variable depending on the resources of the University: some programs have developed summer internships to provide a clinical immersion experience, while others have sought to bring the immersion during a more conventional classroom setting [6]. Literature has reported that these programs which provide effective immersion experiences result in an increase in students' self-reported knowledge and skills, in addition to general confidence. These experiences often extend beyond needs identification, as students connect with potential users and witness the community impact. It also creates room for interdisciplinary involvement, such as the partnerships that could be formed with a medical school and its students [7]. Clinical immersion is a form of experiential learning, in which students engage in atypical learning environments to connect previously learned concepts with experiences [8]. This allows students to draw connections between what they learn during lectures and what they observe in their local environment.

We have developed a semester-long, 1 credit hour course titled Clinical Observations and Needs Finding. The course is officially designated as service-learning due to the strong involvement with the local community and the aim to close the gap in local healthcare disparities; projects developed by students are intended to ultimately aid local clinician partners. While the course aims to increase students' technical skills as related to the design process, it also aims to build confidence and develop students' abilities to work not only with their peers but also with instructors and local clinicians. During the students' senior years, they are required to take Senior Design 1 during the fall semester and Senior Design 2 during the spring semester. As a prerequisite to Senior Design, the Clinical Observations and Needs Finding course is intended to introduce students to the design process. Projects that are initially developed in Clinical Observations are intended to be carried to Senior Design, where prototype creation occurs. This course fits logically into the undergraduate biomedical engineering curriculum, but the specific effects of the course and its specific implementation have yet to be quantified.

While immersive clinical experiences are vital for the student's abilities to identify gaps in current healthcare, not all institutions offer such a program [9]. Additionally, given the diversity of such programs across the country concerning resources available, such as length of immersion, proximity to a major medical school, teaching hospital, active residency programs, etc., it is challenging to derive a universal "one size fits all" approach for such a course, as well as challenges in reporting their efficacy [10] – [12]. The objective of this paper is to examine the efficacy of a junior-level, clinical observations course as developed for our specific regional constraints. We are a land grant state University, the only Ph.D. granting program in Biomedical Engineering in the state, but are located more than three hours from the nearest major research-intensive medical school and teaching hospitals, which presents logistical and collaborative challenges. The rural nature of our state leads to unique healthcare considerations and disparities that present unique opportunities for our students to learn.

Methods

Clinical Observations and Needs Finding is a 1 credit hour course that introduces students to the technical, ethical, and professional responsibilities of biomedical engineers during the product development process. This course is offered in both the fall and spring semesters, with approximately 30-35 students per semester. The course features weekly, one-hour lectures that vary in topics from medical device creation and regulation to HIPAA requirements. During the first several weeks of the course, students are placed in a variety of nearby medical clinics, private hospitals, and some University-affiliated allied health sites where the students are tasked with identifying current needs and gaps related to healthcare and technology. The students attend these shadowing visits in groups of 1-3, and must participate in a minimum of three visits. Students also receive training, prior to conducting observation visits, on professionalism in clinical settings, and instruction on how to optimize observing time and how to interview clinical staff and engineering professionals. These clinical visits are organized by the current and past instructor of the course. Some relationships grew from previous research collaborations while others grew from "cold calling." All of the clinical and industry partners who participate in hosting students are highly motivated and interested in participating in the design process. Upon the students' return to the classroom, the students present their identified needs and proposed solutions individually in the form of a one-minute elevator pitch. Out of these potential projects, half are selected to be developed further into solutions. Students are then split into teams and spend the remaining weeks of the course developing their solutions for their final project design brief. The final presentation of this brief includes a more formal description of the need addressed, the background physiology or pathophysiology relevant to the problem, the initial design of the device, a market analysis and proposed testing and development strategy. Some clinicians and industry partners choose to work alongside the students in the development of prototypes in the subsequent Senior Design course.

This course is officially designated as a service-learning course, as it allows students to engage with healthcare partners in the local community and potentially help close the gap between disparate qualities of care. The course is strategically located in the curriculum as a pre-requisite to the senior design course. During the 1-credit hour Clinical Observations and Needs Finding course, students are focused on identifying needs and gaps in local healthcare settings. While they are introduced to solution development and the design process, depth of learning is limited here by time constraints. Students further develop these skills in the subsequent Senior Design 1 and 2 courses. In the first of these two courses students establish which project they will work on and conduct background research. This first course is focused on designing a solution and planning the creation of a prototype. Senior Design 2 entails the creation of a prototype and subsequent presentation of the students' research. Since all three courses are required, there is a logical flow and continuation of learning throughout the students' junior and senior years.

While this course focuses on increasing the technical skills of students, it also intends to improve their abilities to work in a team and think critically about product design. These goals of the course are explicitly stated in the course objectives. To quantify the efficacy of the Clinical Observations and Needs Finding course as it specifically relates to our geographical location and available resources, pre—and post—course surveys were analyzed both qualitatively and quantitatively. To directly tie the methods of analysis to the nature of the course, the learning objectives remained forefront during the survey creation portion of the process. The objectives of the course as listed in the syllabus are as follows:

Course Objectives; At the successful completion of this course, the student will be able to:

1. Engage in the development of biomedical products and processes from ideation to production;
2. Understand the ethical and regulatory requirements for the development and marketing of such products;
3. Understand the creation, protection, and commercialization of intellectual property;
4. Communicate ideas, proposed solutions, project status, and product development issues to others including those who are not technically trained;
5. Understand the lessons of prior occurrences of failures of biomedical devices due to failures in design and how to apply those lessons to the product development process;
6. Work successfully in a self-directed, project-focused team to develop a biomedical device or process design that addresses a real-world problem.

The perceptions and opinions of students were measured through a Qualtrics survey that was administered during the first week of the course and again during the last week of the course. The survey contained Likert scale questions in addition to open-response questions. The questions evaluated students' interest in the development of medical devices in addition to their understanding of the FDA approval process. The survey was designed to target and evaluate skills necessary in the clinical needs-finding process to better quantify the effectiveness of the course without asking leading questions. These questions have been adapted from our previously published work [13]. The survey questions were intended to align directly with the objectives of the course, as stated in the syllabus. Generally, the questions can be separated into four sections by the themes they aim to measure. The first section is centered on self-efficacy. The second section is focused on connections, value creation, and curiosity, the 3Cs from the KEEN framework for entrepreneurial-minded learning [14]. The third section simply asked students about their interests. The fourth section included three open-response questions. The University Institutional Review Board (IRB) approved the current study (IRB protocol #: 2209420237).

The survey questions analyzed are as follows:

Self-efficacy

1. I can design products to solve a real-world problem?
2. I can identify a test to improve a product?
3. I definitely could become an engineer?
4. I could definitely become an inventor?
5. I am sure in my ability to provide relevant solutions as an engineer?

Connections, Value Creation, and Curiosity

6. I can understand the motivations and perspectives of customers?
7. I can collaborate in a team setting?
8. I can communicate engineering solutions in economic terms?
9. I enjoy thinking in more innovative ways?
10. I know how to make connections with what I learn in class and the real-world engineering problems?

Interest

11. Do you have an interest in developing a medical device?

Open Response

12. How the clinical needs finding course affected your knowledge/perception about how engineering solutions are implemented in a clinical environment?
13. What do you know about service learning? If you know anything about service learning, can you comment on how it may/may not be effective tool in Biomedical Engineering Education?
14. How do think the Clinical Needs Finding course can help with giving back to the community to minimize the local healthcare disparities?

Questions 1-10 were Likert-scale questions, while question 11 was a simple yes or no question. Questions 11-12 were open-response questions. Each question can be aligned to one or more of the course objectives (see introduction). Questions 1 and 2 align with the first learning objective, while questions 3 and 4 are more centrally aligned with objective 6. Question 5 was created based on objective 5, but also tests objective 6. Generally, the questions from the self-efficacy section can be said to align with the 1st, 5th, and 6th learning objectives. In the second set of questions, question 6 aligns closely with the goals stated in learning objective 4. Question 7 is team-oriented and therefore centered on the 6th objective. Question 8 is aligned to objective 4 also, whereas question 9 is focused on objective 3. Question 10 integrates the goals of objectives 2 and 6, focusing on real-world applications. While the final question does not fit as neatly into a single objective, it was written to summarize the general interests of the students. Questions 1-11 were analyzed using Microsoft Excel to create figures that visually displayed the survey responses.

Table 1: Correlations between the Likert-scale survey questions and the course objectives.

Question	Objective
1 – I can design products to solve a real-world problem?	1, 5, & 6
2 - I can identify a test to improve a product?	1, 5 & 6
3 - I definitely could become an engineer?	1, 5, & 6
4 - I could definitely become an inventor?	1, 5, & 6
5 - I am sure in my ability to provide relevant solutions as an engineer?	1, 5, & 6
6 - I can understand the motivations and perspectives of customers?	4
7 - I can collaborate in a team setting?	6
8 - I can communicate engineering solutions in economic terms?	4
9 - I enjoy thinking in more innovative ways?	3
10 - I know how to make connections with what I learn in class and the real-world engineering problems?	2 & 6

The final section of the survey consisted of solely open-response questions; they were separated from questions 1 –11 due to differences in analytical methods. The analysis of qualitative questions has long been prone to researcher bias due to the lack of a statistical method of analysis or other means of quantifying written responses. NVivo is a qualitative analysis computer software that allows researchers to discover patterns and trends without bias and cherry-picking. NVivo has been used in the literature to analyze survey responses, students' writing, and interviews [15], [16]. It is a multifunctional tool and can be used to perform both thematic and sentiment analysis. To analyze questions 12-14, the pre—and post—course survey data was uploaded to the software in separate files. A sentiment analysis was then performed on each of the files, using auto coding, to produce a broad categorization of positive, neutral, and negative responses. NVivo categorizes positive, negative, and neutral sentiments by auto-coding each word and analyzing the sentiment in isolation, meaning that context is not included in this calculation. Words are recognized by the software to have a preexisting sentiment score with ranges of very negative, moderately negative, neutral, moderately positive, and very positive. The score for each word determines its place on this scale; however, the score can change if preceded by a modifier (like "more" or "somewhat"). Words with a neutral sentiment are not coded [17].

To quantify differences in IP creation, the Office of Technology Ventures provided data on the number of invention disclosures, patent applications, and patents awarded. Long term, IP generation can be better quantified via actual awarded patents and this will be tracked in future work. We ran a query against all the Biomedical Engineering undergraduate students from 2013 to 2022 to obtain these numbers.

The survey, which was administered through Qualtrics, also collected demographic information from each participant. This information included race, ethnicity, first-generation status, gender, and age group. This demographic data was collected so future studies could test for differences between different groups. The students surveyed for this project included 75, junior-level undergraduate biomedical engineering students. The demographics of this sample can be seen below, represented as a percentage.

Table 2: Demographics of survey participants

Race	White	80%
	Black	4%
	Asian	9.3%
	American Indian/Alaska Native	2.6%
	Other	4%
Ethnicity	Non-Hispanic	81.3%
	Hispanic	17.3%
	N/A	1.3%
First Generation	Yes	14.7%

	No	85.3%
Gender	Male	46.7%
	Female	53.3%
Age Group	18-20	56%
	21-23	38.7%
	24-26	5.3%

Results

A. Quantitative Analysis

1) Self-efficacy: The first section of questions aimed to evaluate students' self-efficacy, as it relates to their skills as an engineer. Self-efficacy is a quality used to determine the extent to which students believe they can perform tasks and solve problems. It is closely related to confidence. Bandura's theory of self-efficacy first suggested that those with high self-efficacy could experience better focus and less anxiety [18]. Researchers interested in education have continued to use Bandura's work to further understand the relationship between self-efficacy and various types of success. In the field of biomedical engineering, greater self-efficacy correlates to greater academic performance and subsequently work performance [19], [20].

In a biomedical engineering curriculum, it is vital to develop an innovative mindset in students. Engineers are frequently tasked with developing a solution for a problem, and often a new solution is needed. Innovation is necessary for the forward movement of society, as it entails something novel that is valued by the market. An innovation could be a physical product, or it could be a process, but it must be valued by society [21]. Included in this is the ability to apply concepts learned in class to observed problems. In biomedical engineering, innovation comes in the form of device development, a goal of course objective 1. The results of Question 1 are displayed in Figure 1. This question primarily served to quantify students' confidence as related to medical device design and real-world implementation. Before completion of the course, only 12% of students strongly agreed with the statement. During the second administration of the survey, 25% of students strongly agreed.

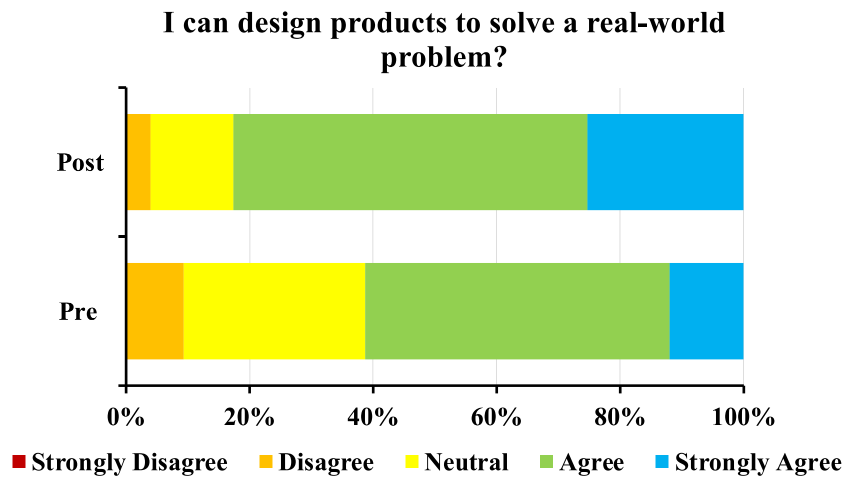

Figure 1: Question 1 survey responses

Also included in the technical skills expected of new graduate engineers, is the ability to test and evaluate a new design. Navigating the rules and regulations of the process of Food and Drug Administration approval can be difficult. By teaching students about this process early on, they will likely keep these restrictions in mind when developing a new technology. Question 2, seen in Figure 2, aimed to determine how confident students were at identifying a test to improve a product. Following completion of the course, about 93% of students agreed or strongly agreed with the statement, a noticeable increase from the initial data.

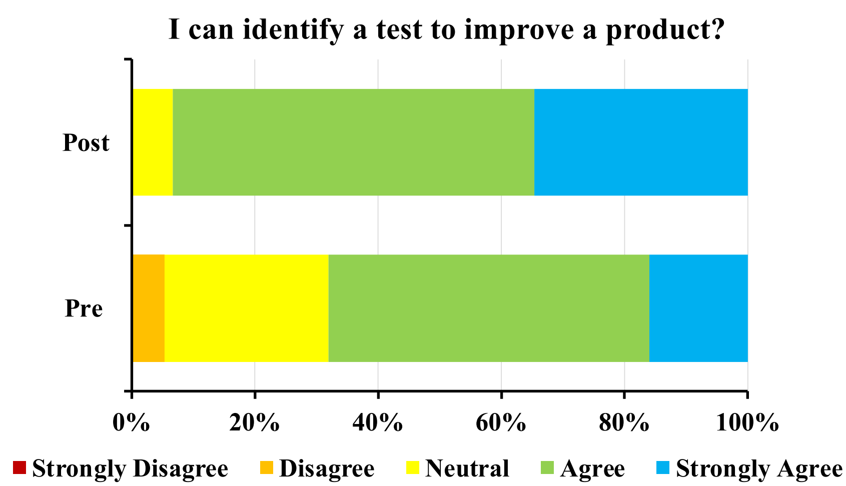

Figure 2: Question 2 survey responses

Further related to self-efficacy are the students' self-reported beliefs. The survey asked about two beliefs specifically, the ability to become an engineer and the ability to become an inventor. Before completion of the course, the students' responses were overwhelmingly positive, with 93% reporting to agree or strongly agree with the statement. Following the completion of the course, this number increased slightly to 96%. More students reported to strongly agree with the statement in the post-course survey than in the pre-course survey.

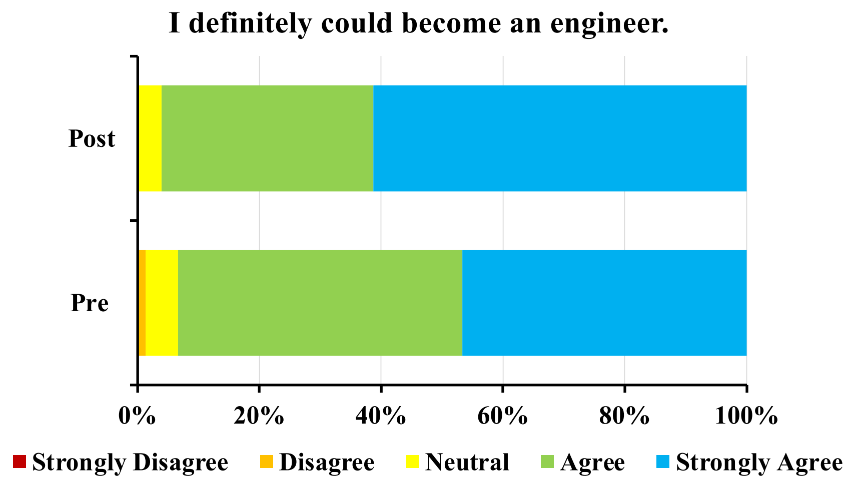

Figure 3: Question 3 survey responses

Closely related to the students' self-reported beliefs about becoming an engineer are their self-reported beliefs about becoming an inventor. Before completion of the course, only 61% of the students reported to agree or strongly agree. After the course, this number increased to 75%, and no students reported to disagree. This question can be closely connected to the number of patent applications received before the installation of the course and in subsequent years. While this course primarily focuses on needs identification, it is a prerequisite to both senior design 1 and 2 which extensively cover solution development. Many of the projects that result from this course are further developed in senior design. Due to this, the clinical observations and needs-finding course is a piece of the senior design enterprise and therefore has an indirect impact on intellectual property generation.

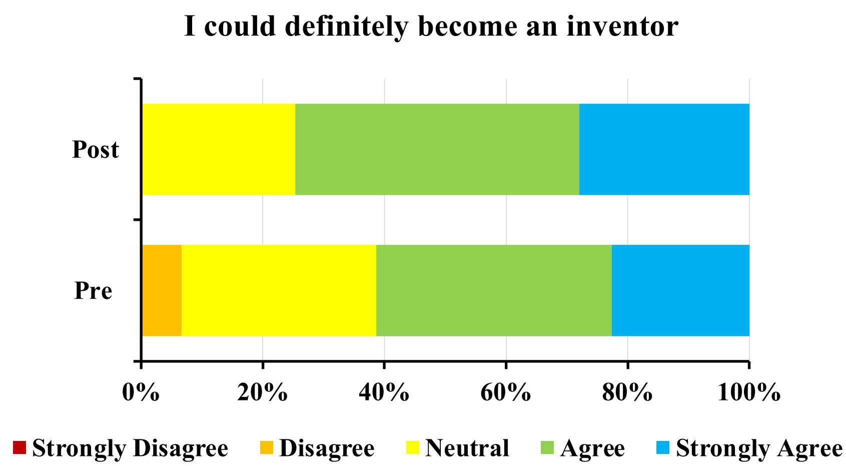

Figure 4: Question 4 survey responses

More specific to the purposes of an engineer, are the students' beliefs about their abilities to generate solutions. It is intended that recent graduate engineering students will be able to think critically about a problem and generate solutions [22]. The changes in students' responses were visible on this question. Prior to the course only 11% of students strongly agreed with the statement. After the course, this number increased more than three times, to 37%. Additionally, no students reported to disagree with the statement, and the number who reported feeling neutral after the course significantly decreased.

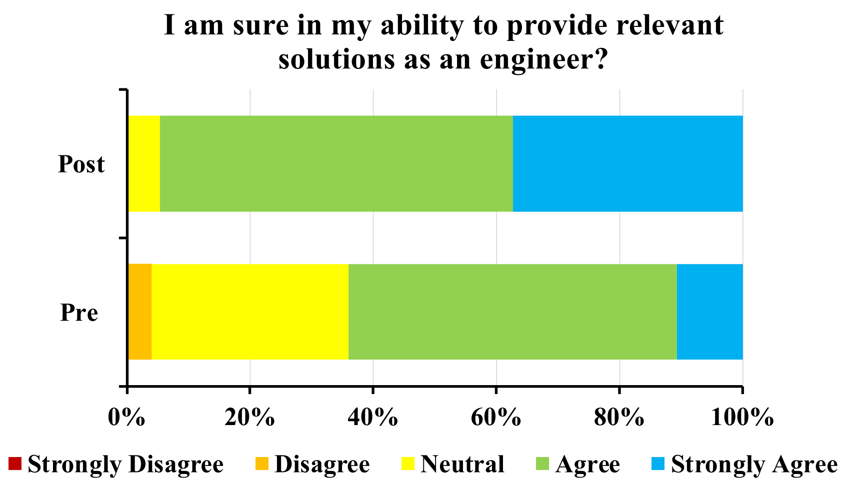

Figure 5: Question 5 survey responses

2) Connections, value creation, and curiosity: The second section of questions was focused on evaluating the students' abilities to form connections, understand value creation, and innate curiosity. These attributes describe students' opinions and general interests in solving real-world problems.

In the development of a new technology, it is vital to first understand the needs present. This course was structured to allow students to first observe needs in a clinical setting, and then design a technology that would be a solution. Within understanding a clinical problem is understanding the motivations and perspectives of customers. A crucial element of designing and selling a new technology is product-market fit. There must be a need for customers to be willing to purchase something. Because of this relationship, it is valuable for students to understand how to identify and evaluate the potential market of their technology. In the pre-course survey, 25% of students reported to strongly agree with the statement. In the post-course survey, this number increased to 35%. The number of students who reported neutral was decreased from 18.9% to 9.4%. In the post-course survey, no students reported to disagree with the statement.

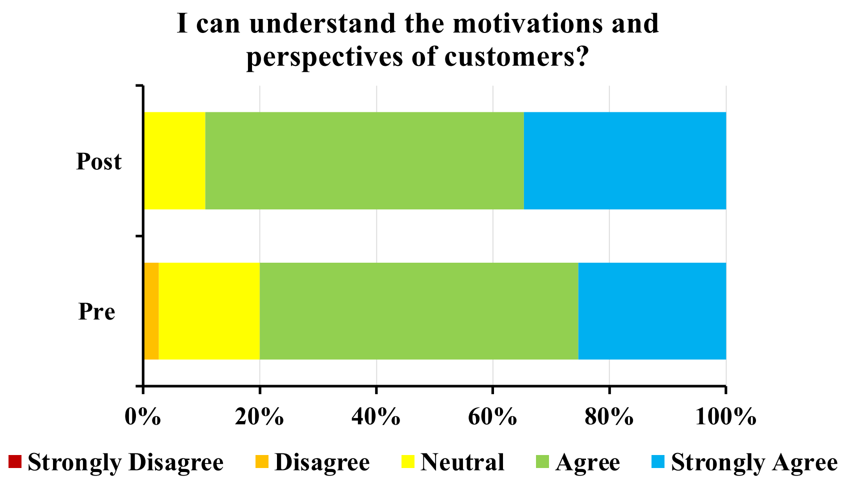

Figure 6: Question 6 survey responses

In the field of biomedical engineering, collaboration with a team is necessary. Many companies rely on a team-structured organization in the development of new technologies and products. While team-based work has become an effective method of production, it has also been found to increase innovation [23]. In our biomedical engineering undergraduate curriculum, there are various required team projects, including the subsequent senior design project. It is advantageous for students to learn how to work in a team setting earlier in their careers. Although the data shows a positive response in the pre-course survey, there was still an increase in the percentage of students who reported to agree or strongly agree with the statement. Before completion of the course, 93% of students reported to strongly agree or agree; following the course, this number grew to 99%.

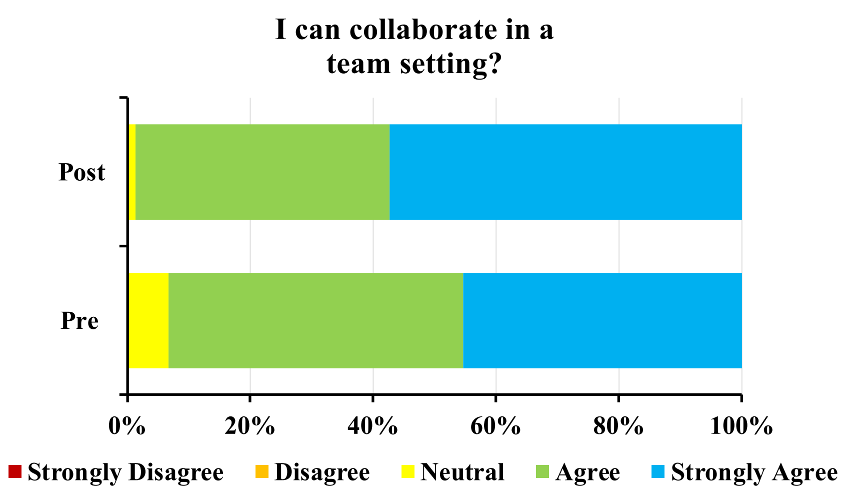

Figure 7: Question 7 survey responses

Closely related to the motivations and perspectives of customers is the business side of marketing a new technology. This relies on a rudimentary understanding of basic economics, and how to explain their technology with economics in mind. In the pre-course survey, 19% of students reported to strongly agree, and 9% disagreed. In the post-course survey, 33% strongly agreed and 3% disagreed.

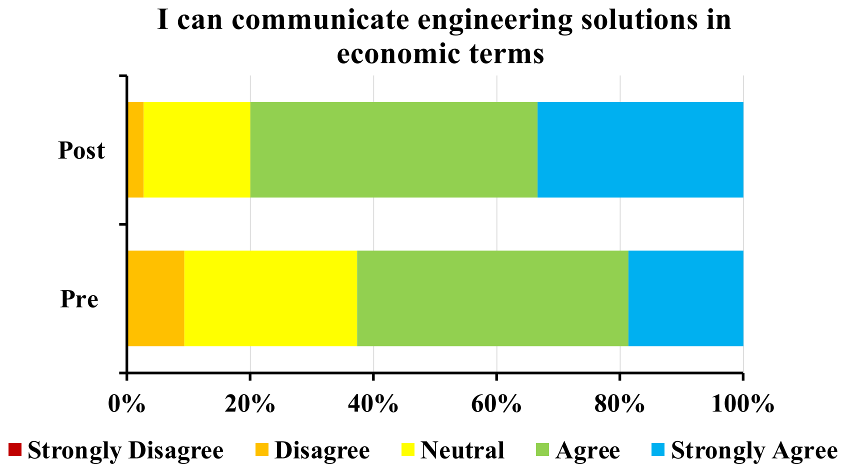

Figure 8: Question 8 survey responses

While technical skills are important, the interests and passions of students are just as valuable. It is desirable that engineers enjoy their jobs, and therefore students enjoy their coursework to an extent [24]. In a course that allows creative freedom, it is intended that students think out of the box. This course was structured with less traditional lectures and more clinical observation time. In the survey responses to this question, there was an increase in the percentage of students who strongly agreed with the statement, from 39% to 49%.

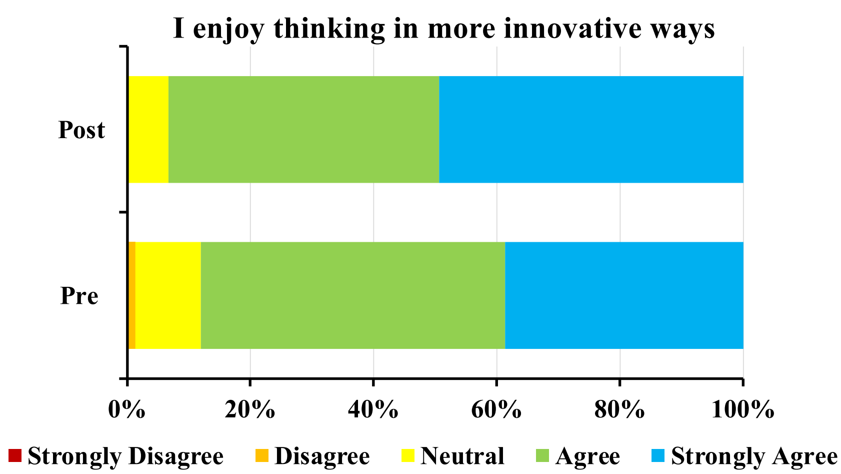

Figure 9: Question 9 survey responses

A critical step in the development of successful engineers is the ability to make connections. This includes connections between observed problems and generated solutions. It also includes the ability to apply skills learned in traditional courses to the development of a real-world solution [25]. The pre-course survey found that 16% of students strongly agreed with the statement, while the post-course survey saw this number increase to 33%. The percentage of students who disagreed decreased from 4% to 1.9%.

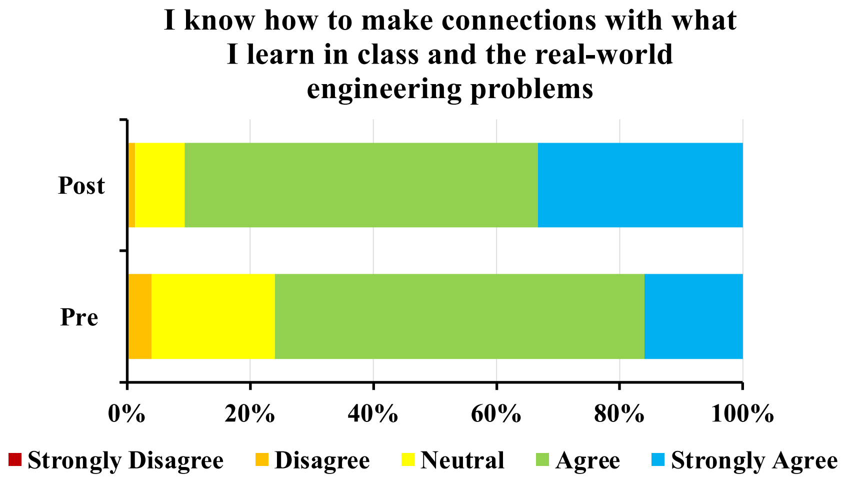

Figure 10: Question 10 survey responses

3) Interest: The final section of questions was used to evaluate the general interests of students. Our program hosts of wide range of biomedical engineering students, with some students intending on entering the industry, while others are pursuing professional schools. From the pre-course to post-course survey, the number of students who reported having an interest in developing a medical device did not change.

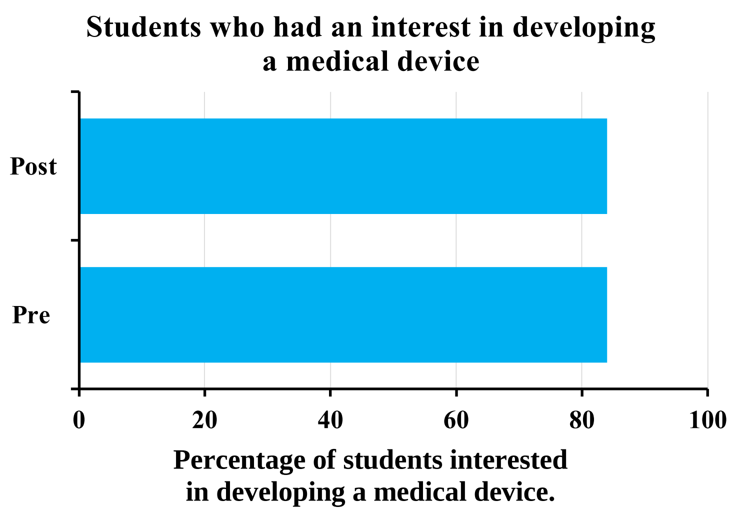

Figure 11: Question 11 survey responses, reported as the percentage of students who responded Yes to having an interest in developing a medical device.

B. Qualitative Analysis

NVivo, a qualitative analysis computer software, was used to analyze the responses from the three open-response questions. The following sentiment analyses were produced through the software using the auto-code option.

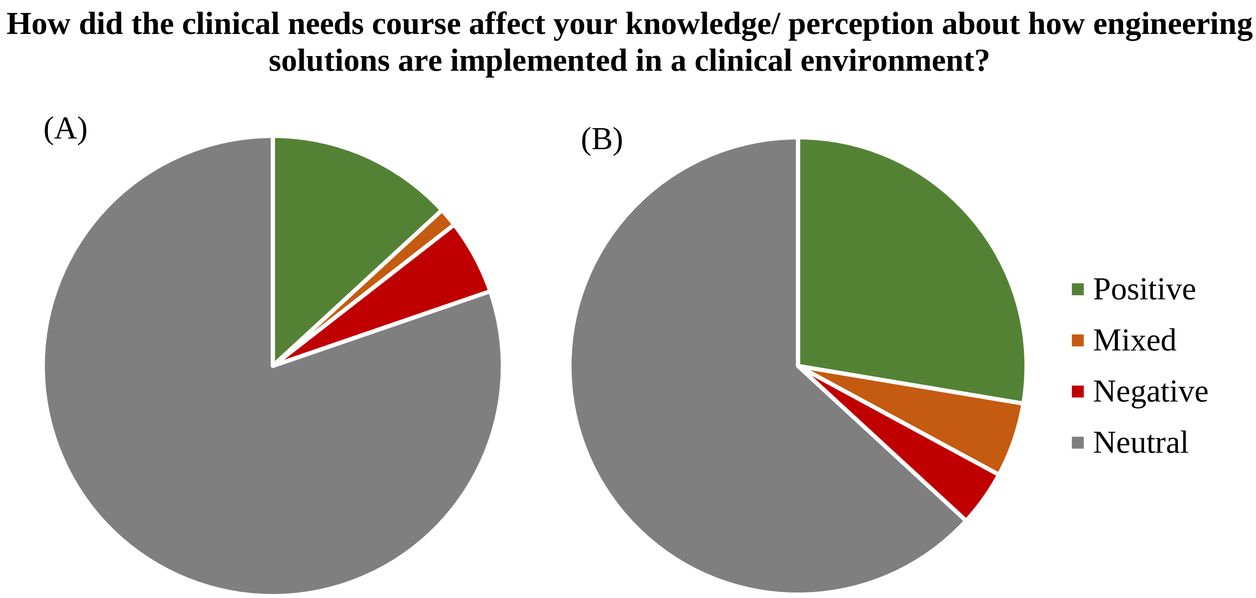

Figure 12: Question 12 – "How did the clinical needs course affect your knowledge/ perception about how engineering solutions are implemented in a clinical environment?" pre-survey (A) and post-survey (B) NVivo produced sentiment analysis. Pre-survey: 13.2% positive, 1.3% mixed, 5.3% negative, and 80.3% neutral. Post-survey: 27.6% positive, 5.3% mixed, 3.9% negative, and 63.2% neutral.

A comparison of the above question displayed over a 100% increase in positive sentiment and a decrease in negative sentiment between the pre- and post-surveys. After the course, students responses were more positive regarding learning in a clinical environment. This could be attributed to preparatory lectures provided during the course, but also to experiential learning that occurred during the students' visits.

What do you know about service-learning? If you know anything about service-learning, can you comment on how it may/may not be an effective tool in Biomedical Engineering Education?

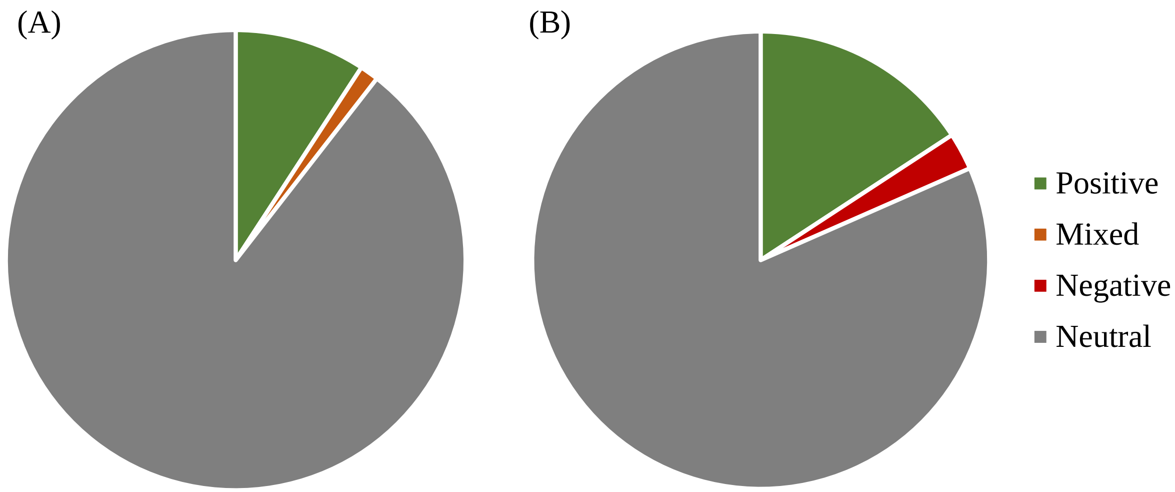

Figure 13: Question 13 – "What do you know about service-learning? If you know anything about service-learning, can you comment on how it may/may not be an effective tool in Biomedical Engineering Education?" pre-survey (A) and post-survey (B) NVivo produced sentiment analysis. Pre-survey: 9.2% positive, 1.3% mixed, 0% negative, and 89.5% neutral. Post-survey: 15.8% positive, 0% mixed, 2.3% negative, and 81.6% neutral.

The near doubling of the positive sentiment indicates that many students believe service learning to be beneficial to their current careers as students. However, there was a slight increase in negative sentiment from the pre-course to the post-course survey.

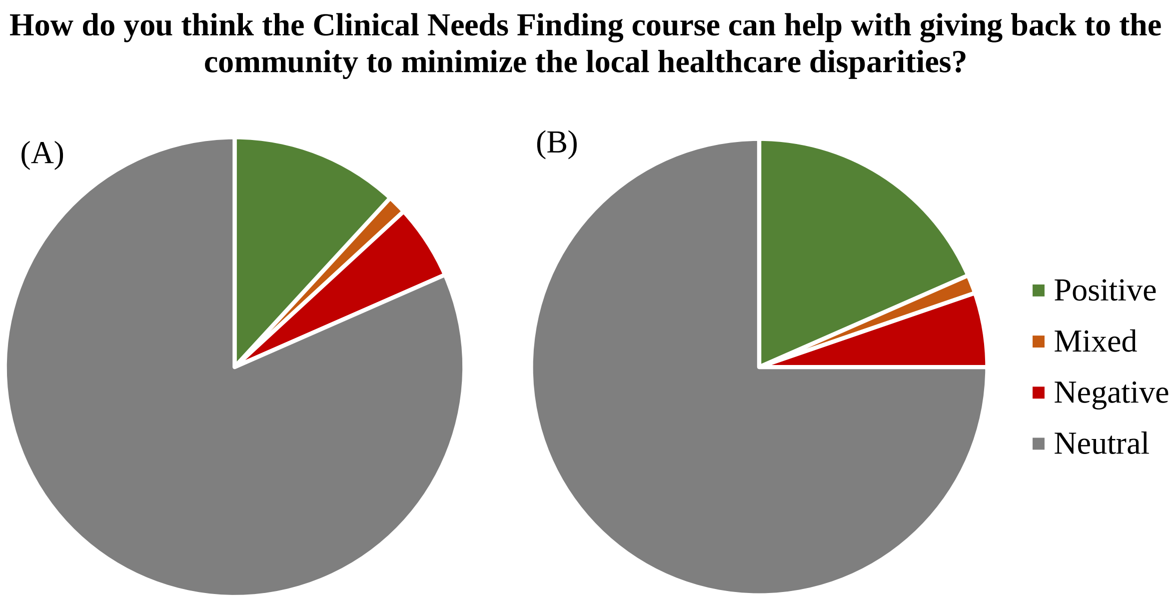

Figure 14: Question 14 – "How do you think the Clinical Needs Finding course can help with giving back to the community to minimize the local healthcare disparities?" pre-survey (A) and post-survey (B) NVivo produced sentiment analysis. Pre-survey: 14.5% positive, 1.3% mixed, 5.3% negative, and 81.6% neutral. Post-survey: 18.4% positive, 1.3% mixed, 5.3% negative, and 75% neutral.

There is a slight increase in positive sentiment in the post-course assessment, although a significant number of responses remained neutral. It is possible that this slight increase can be attributed to experiential learning during the students' visits. The negative sentiment remained the same in both the pre and post-surveys, leaving room for improvement in the course's content.

Discussion

In the first section of questions, all 5 questions saw an increase in positive student responses after the conclusion of the course. While there is variation in the magnitude of this shift, it was consistently positive. Out of these 5 questions, questions 1, 2, and 5 saw the greatest increase in students who reported to strongly agree with the statement. A difference between questions 1,2, and 5 and questions 3 and 4 is the wording of the statement. While 1, 2, and 5 are definite claims such as "I can" or "I am," questions 3 and 4 are more unsure in nature, and worded "I could." During the mid-20th century, several experiments were conducted on survey question wording and format. While the literature is not as specific as to discuss our question differences, there is evidence to suggest that wording can alter participant responses [26]. Questions 3 and 4 also had more than 80% and 60%, respectively, of students report to strongly agree or agree before taking the course. This suggests that the small change in students' responses may be attributed to the fact that many students already agreed with the statement. While there was little change in the responses to questions 3 and 4, it is a positive outcome to note that our students are already relatively confident in their abilities to become future engineers and inventors.

In the second section, all questions reported a visible, positive shift in student responses. In question 6, over 89% of students reported to strongly agree or agree with the statement following the completion of the course. This is an increase compared to responses taken prior to the course, suggesting that the course successfully teaches students how to understand the point of view of a customer. Question 7 reported the smallest change in student responses. When analyzing the pre-course responses, it became clear that the students claim to be able to collaborate in a team setting. Although this question reported little change across the two surveys, it is worth noting that a large majority of the students reported to agree or strongly agree prior to the course. This could be attributed to prior courses in the department that require group project work. In the post-course survey, the number of students who strongly agreed with the statement slightly increased. Questions 8 and 10 reported more significant changes in student responses than question 9. While questions 8 and 10 ask about technical skills, question 9 inquires about the students' levels of enjoyment. This difference suggests that the course is more successful at increasing the students' technical skills and knowledge than altering their interests and enjoyment. This may be due to the fact that students have more room to grow in terms of their technical skills, and are conversely, more decided on their interests. Due to student self-selection in the field of biomedical engineering, many students enter the course with relatively high levels of enjoyment. This may be due to prior courses within the department.

The third section of questions is straightforward – a simple yes or no question asking students whether or not they have an interest in developing a medical device. While there was a large number of students who reported "yes" prior to taking the course, this number did not change following the completion of the class. It is positive that a large majority of the students entered the course with such sentiments, but frustrating that we were unable to sway the remaining holdouts. Biomedical engineering graduates enter into a variety of fields post-graduation, including industry, graduate school, or professional school. Those who enter into industry are likely to take an interest in one of three fields: biomedical instrumentation, biomechanics, or bioprocessing [25]. In these careers, students are likely to be involved in the development of novel medical technology. Acknowledging these career trajectories, it is preferred that students maintain some interest in device development. As for the high percentage of students who answered "yes" in the pre-survey, this could suggest that prior courses have aided in fostering interest. There is also the potential impact of this prior interest on other elements of the survey, such as the large number of students who agreed with the question in the pre-course survey in questions 3 and 4. Future research could explore this correlation further.

The fourth section of questions attempts to analyze the students' confidence in real-world scenarios due to the knowledge inherited from this course, as well as the overall effectiveness and applicability of this type of learning. Each question displayed an increase in positive sentiment, allowing the conclusion to be drawn that the course properly prepared students for the clinical opportunities as well as provided some necessary experience for students to succeed in their future careers. Students can see and describe the benefits the course offers for local healthcare professionals and their mindset as they enter these careers.

The results for each section of questions provide information aiding in the evaluation of this course. Between the pre-and post-surveys, each question involving self-efficacy demonstrated a positive increase, indicating that the course provided students with enough experience and knowledge to benefit their skill sets. Measurements of self-efficacy are of particular interest to researchers due to their prominence in the literature and correlations to various factors, such as academic success and career choice. Self-efficacy is not defined by the skills an individual possesses, but by how they can use those skills; it is a judgment of capabilities that in turn influences performance [20]. If the course can increase self-efficacy in students, there is the potential to see increases in academic performance, enjoyment, and career confidence. The section of questions involving Connections, Value Creation, and Curiosity also displayed a net positive increase in student responses. The advancements students make in their networking, innovation, and critical thinking are apparent through this positive change. The open-response section of questions continued to allow for a sentiment-style method of analysis that was simplified using autocoding. Every question that was analyzed exhibited an increase in positive sentiment, directly relating to the advantages the course has to offer. It is important to analyze our results not only in isolation but also within the current landscape of literature. The Clinical Immersion program developed by S. Stirling and M. Kotche [7] at the University of Illinois at Chicago saw similar results and value in clinical observations. Similar to this study, B. Przestrzelski and J. DesJardins [2] at Clemson University found their clinical immersion program to be beneficial for preparing students for their senior design course. This study also found the class of students at the time of participation impacted the level of influence the program had, with graduate students less influenced than rising juniors and seniors. This suggests that the timing of a clinical observations course could be impactful in determining its usefulness. As our course is offered during our students' junior years, it is significantly impactful on the futures of our students. Since the Clinical Observations and Needs Finding course is offered in both the fall and spring semesters, future studies could analyze whether or not there is variation between the two offerings based on timing. Future work could also examine the impact of incorporating needs findings into earlier courses in the curriculum. It is reassuring to note that our results agree with those found in the current literature, despite differences in the design of such courses and programs.

A. Limitations and Future Work

While the results of this study were mostly encouraging regarding the evaluation of the Clinical Observations and Needs Finding course, there are still shortcomings worth discussing. One limitation of this study relates to the sample size. While each course iteration holds approximately 30 students, several semesters' worth of data were used to complete this research, to generate a sample size of 75 students. As these students did not experience the course in the exact same way, there may be variation across the different offerings of the course. However, this could also be viewed as an opportunity, as the instructors can make changes each semester based on student feedback collected through this study. Future work and continuous improvement of the Clinical Observations and Needs Finding course will include broadening the breadth of clinical sites and engineering firms that are available to meet with our students, with the goal of enhancing students' exposure to a wider range of clinically important problems. As additional sites are brought online, we anticipate students' ability to identify which problems are suitable for an engineering design solution will improve, and these abilities will be examined in future engineering education assessments and publications.

Conclusion

The purpose of this study was to quantify and determine the efficiency of a clinical observations and needs-finding course adapted for our specific geographical and resource constraints. We are a large, land-grant University located in a rural state, without proximity to a major teaching hospital. This course aimed to introduce students to the product design and development process by first teaching needs identification through a service-learning format. The results of the study indicate that the class was overall successful at increasing positive perceptions in the minds of students regarding device creation, real-world application, and practical skills. Although the idea of clinical immersion is not novel, our course is unique in that it has been adapted to provide students with clinical experiences, despite lacking access to a medical school. This course is intended to educate students on the engineering design process while also maintaining a sense of belongingness within the program as a whole. The results are encouraging, suggesting that while students are obtaining technical skills, they are also growing in confidence and leaving the course encouraged. As a service-learning course, we plan to further develop relationships with clinical and industrial partners to create opportunities to give back to our local community. We plan to continue to develop the course to create the greatest benefits for our students in preparing them as engineers.

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