WIP: Short-term Clinical Immersion Program's Impact on Undergraduate Bioengineering Student Self-Efficacy

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Abstract

Undergraduate biomedical and bioengineering programs increasingly utilize immersive clinical experiences to bridge the gap between academic coursework and real-world clinical challenges. These programs have demonstrated efficacy across numerous institutions, though scheduling remains challenging, particularly at universities operating on cooperative education schedules with alternating six-month academic and work periods. To address this constraint, a unique four-day clinical immersion program funded by the National Institutes of Health was developed in 2023. The program enrolls fourth-year students interested in rural health in a semester-long preparatory course, facilitates a four-day clinical immersion trip to rural healthcare sites, and engages students in developing clinically relevant capstone projects based on observed needs. This short-term model offers potential for developing critical engineering skills at reduced cost compared to traditional extended programs.

Program impact is evaluated across three student groups: Immersed (trip participants), Involved (non-participants working on trip-derived projects), and Control (students on unrelated projects). Anonymous self-efficacy surveys assess confidence across twelve engineering tasks following capstone completion. Results from two cohorts (2024-2025, n=101 respondents) show Involved students demonstrated significantly higher confidence in prototype building (p=0.002) than Control students and Immersed students reported positive confidence trends in immersion-taught skills but statistical differences are not observed. Qualitative analysis revealed Immersed students gained deeper understanding of complex rural health challenges and reported mostly positive experiences. However, skill dissemination from Immersed to Involved students proved limited. This work-in-progress examines two cohorts of an ongoing five-year program, demonstrating that abbreviated clinical immersion experiences can effectively enhance student self-efficacy and clinical understanding.

Introduction

Clinical immersion experiences for undergraduate bioengineering and biomedical engineering (BioE) students are important for translating skills from classroom concepts to real-world application [1]. Knowledge is most effectively acquired through participation in authentic communities of practice rather than decontextualized instruction [2], and clinical immersion programs offer this opportunity. Prior clinical immersion programs have been shown to improve students' self-efficacy in important BioE skills such as needs-finding, design implementation, and cross-discipline communication [3]. While many BioE programs have created successful clinical immersion experiences ranging from 4 weeks to a year, Northeastern University is unable to apply these existing models due to its unique schedule which lacks summer breaks [4]. Thus, a short-term, NIH funded, clinical immersion program has been developed and run since 2023 that works in conjunction with the Northeastern University BioE Capstone class. This study aims to examine the impact of this short immersion program on undergraduate BioE student self-efficacy towards engineering skills in medical device design.

Methods

The BioE capstone class is a 6-month, 2-class experience where student teams of six develop and test a solution to an engineering problem. The Short-Term Clinical Immersion Program, the topic of this study, immerses students in rural healthcare settings to inspire clinically relevant capstone projects. A visual map of the program is presented in the appendix (Figure A1), the structure of the program is as follows. Students apply for the program with their resume and a short written explanation of their motivation for participating in the program. Students who are aligned with the project mission and have competitive GPAs are accepted to the program. Between January and April, students complete a course on rural healthcare in the United States to prepare them for the immersion trip. In April, for four days, students and faculty travel to various clinical and academic sites in rural regions of Maine. This trip includes a day-long needs-finding class, clinical shadowing at various rural clinical sites, and a debrief and brainstorming session for students to generate capstone projects based on observed clinical needs.

In July, all capstone students rank project preferences across all possible projects and are assigned to projects in teams of six. Students who go on the immersion trip, labeled as Immersed Students, are guaranteed placement on one of the projects they develop. Students who do not attend the trip but are assigned to projects developed from the trip are labeled Involved Students; remaining students who do not work on these projects or attend the trip are labeled Control Students. Between July and December, all three student groups take the capstone class and work to develop a prototype solution for their projects. In December, Immersed and Involved Students return to a clinical site in Maine to present complete prototypes and receive clinician feedback.

To study the impact of this program, an anonymous self-efficacy survey is administered in December to all three groups. Students rate their confidence (0–100 scale) in performing twelve different engineering tasks (Tables A1 and A2). Tasks 1-5 are taught to all the students as part of the capstone course, Tasks 6-10 are only taught to the Immersed students as part of their immersion trip, and Tasks 11-12 are not explicitly taught to any of the students in the course or trip. Immersed Students answer two additional free-response questions regarding their perceptions of rural health and whether program expectations are met (Table A3). Quantitative data is analyzed using Welch's ANOVA ($p \leq 0.05$) and Games-Howell tests for post-hoc analysis; qualitative responses undergo sentiment analysis. This work-in-progress reflects two completed cohorts (2024–2025), with two additional cohorts (2026–2027) funded. The Northeastern University Internal Review Board (IRB) has determined that this proposed activity is not research involving human subjects as defined by the Department of Health and Human Services and does not require IRB oversight.

Results and Discussion

The quantitative survey responses (Immersed n=6/11, Involved n=22/30, Control n=73/126) when examined with a Welch's ANOVA test demonstrate one statistically significant difference in student confidence across the twelve tasks (Figure 1 and Table A2). Confidence levels in tasks taught only in the capstone course are similar across all three groups. Average confidence levels in tasks only taught in the immersion trip are higher for the Immersed students but do not report significant differences. The tasks not taught in the immersion trip or capstone report disparate confidence outcomes. The Involved group reports significantly ($p=0.002$) higher confidence in building a prototype than the Control group, and while not significant the average is much larger for the Involved compared to the Immersed group. In addition, while not significant, the Immersed students report noticeably less confidence in managing solution bias of the clinical partners.

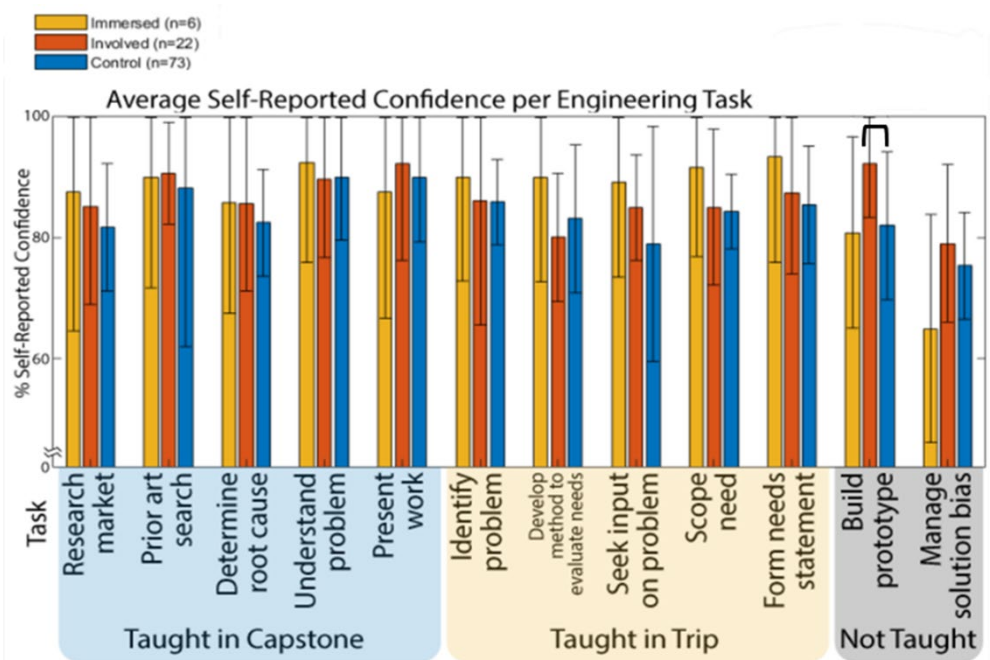

Figure 1. Average Self-Reported Confidence per (abbreviated) Engineering Task. Error bars signify one standard deviation. Statistically significant differences are represented by black brackets.

The lack of differences in confidence levels for tasks taught during capstone is expected. Even though the Immersed students plan the topic of their capstone project in April, Tasks 1-5 are only taught in July with the other students. The skills taught to and practiced by the

Immersed students in April as part of the immersion trip, Tasks 6-10, do not report statical differences between groups but do report noticeably higher average Immersed student confidence. These results suggest the program may have a positive effect on training Immersed students in various components of the engineering design process but a larger sample should be collected to better assess this trend. In 2024 and 2025, the Immersed students work together on a single capstone team, separate from the Involved students, which may prevent the dissemination of these skills. Future Immersion students may be dispersed into each project group developed from the immersion trip to better disseminate their skills.

The Involved students report significantly higher confidence in building a prototype compared to the Control students and larger but not significantly larger average scores than Immersed students. There are two potential explanations. First, the Involved students could have started with more confidence in this task. A substantial limitation of this study is only end of semester surveys are collected. Future cohorts will be given start and end surveys to address this. Second, collaboration with clinicians through the design process may improve the Involved student's confidence in this task. If clinician input boosts prototype-building confidence, Immersed students should report confidence similar or greater than the Involved students, but they do not. This may be because sub-optimal project matching offsets the benefit of clinician collaboration. Immersed students choose from only four projects developed on the trip, which may not fit their skill sets, potentially lowering confidence. Involved students, with fifteen projects to choose from, can more easily select ones matching their abilities. Currently, it is not clear why the Immersed students reported noticeably lower confidence in managing the solution bias. To further investigate this phenomena, additional free response questions will be asked of the next two cohorts on this topic (Table A5).

Sentiment analysis of the free response answers from Immersed students suggests this short immersion trip successfully teaches them how to conduct needs assessments and fosters an interest in designing for underserved populations (Table A3). Immersed students demonstrate a trend of initially having inaccurate perceptions of rural health problems, gaining deeper understanding of complex and unique rural health issues, and overall having positive experiences on the immersion trip. One student states that their "perspective…broadened significantly" after the immersion program, highlighting their suburban and urban background to explain their initial misconceptions about rural health. Northeastern University is located in the center of Boston, so it is not difficult to see how students coming from primarily suburban or urban areas may have limited opportunities to work with rural communities. One student even indicated a newfound interest in innovation for rural healthcare and stated, "I'd love to pursue more projects focused on aiding this population after my experience!"

Conclusion

The positive trend but lack of statistical differences in Immersed student confidence in specific engineering tasks suggest that this short-term immersion program may positively impact BioE student design skills, but results are inconclusive. As institutions seek to balance educational impact with resource constraints, this model demonstrates that abbreviated clinical immersion programs might deliver value as an accessible alternative to traditional extended programs, but more work should be completed before making implementation suggestions.

References

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Appendix

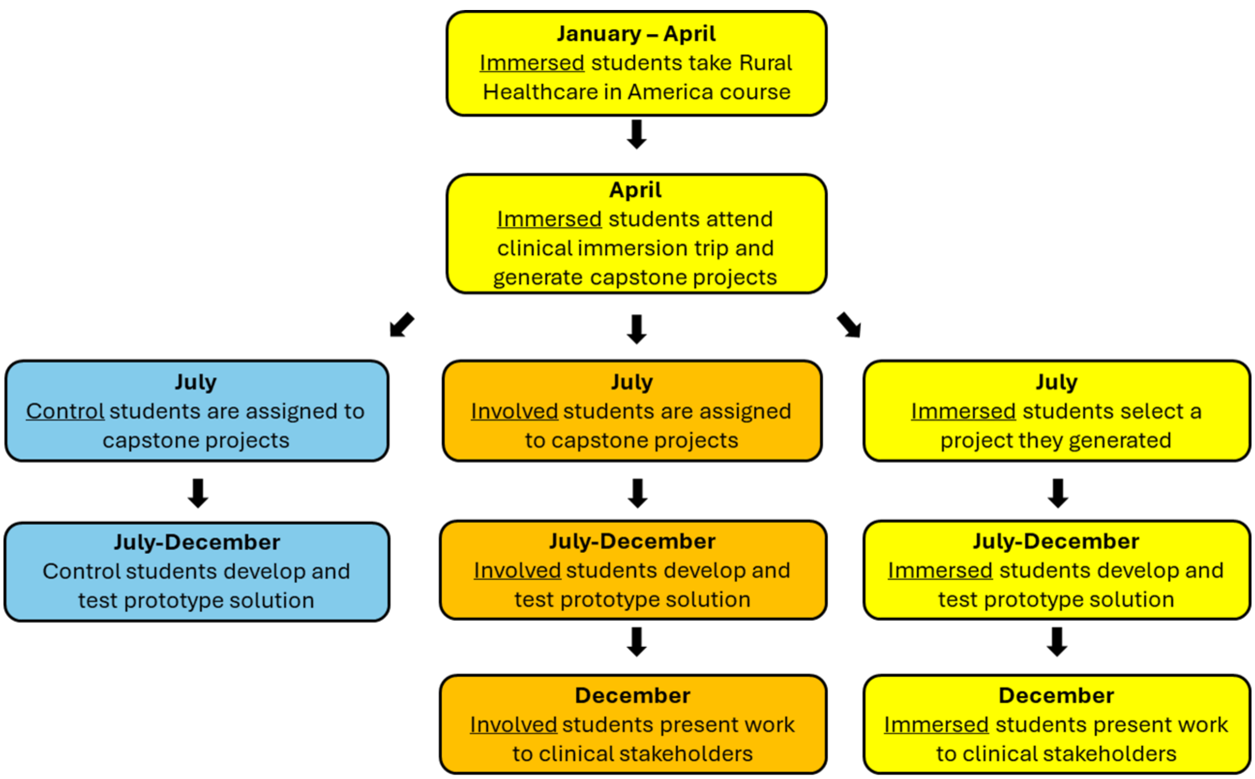

Figure A1. Flowchart of clinical immersion trip and capstone course

Table A1. P-values from Chi-Square test for each task to determine variance of quantitative survey questions

Task	p-value
1) Research the market for potential need	0.040
2) Conduct a prior art search	0.001
3) Determine the root cause of a problem	0.092
4) Understand the problem to be solved	0.213
5) Present your work to potential users	0.112
6) Identify a problem through observation	0.053
7) Develop a systematic method to evaluate needs	0.033
8) Seek input on a problem from stakeholders other than primary user	0.009
9) Scope a need	0.091
10) Formulate a need statement	0.152
11) Build a prototype	0.010
12) Manage solution bias of a client/customer	0.036

Table A2. P-values of Welch's ANOVA to determine if assumption that sample means are equal and Games-Howell test for post-hoc p-values

Task	Welch's ANOVA	Games-Howell p-values		
		Control-Immersed	Control-Involved	Immersed-Involved
1) Research the market for potential need	0.373	0.399	0.594	0.874
2) Conduct a prior art search	0.668	0.943	0.626	0.992
3) Determine the root cause of a problem	0.610	0.744	0.655	0.999
4) Understand the problem to be solved	0.679	0.689	0.998	0.740
5) Present your work to potential users	0.632	0.956	0.648	0.832
6) Identify a problem through observation	0.757	0.738	0.997	0.770
7) Develop a systematic method to evaluate needs	0.113	0.174	0.803	0.165
8) Seek input on a problem from stakeholders other than primary user	0.127	0.164	0.342	0.735
9) Scope a need	0.326	0.315	0.980	0.417
10) Formulate a need statement	0.211	0.199	0.862	0.441
11) Build a prototype	0.011	0.995	0.002	0.580
12) Manage solution bias of a client/customer	0.064	0.153	0.683	0.062

Table A3. Free Response Answers from Immersed Students After completion of 6-month Capstone Course. The following themes are marked with corresponding colors; Red: Initial inaccurate perceptions of rural health problems due to lack of experience. Orange: Rural health problems are complex. Yellow: Rural health problems are unique. Green: Positive sentiments. Blue: Critiques

Question 1: How has your participation in the rural health program influenced your perception of rural health?	
Student 1 (2024)	I enjoyed it and it was good to gain different perspectives
Student 2 (2024)	Coming from a suburban and urban background, I had limited experience and understanding of rural health and living. When I think of rural areas, my mind often conjures images of farmland and woods. However, after participating in the rural health program, which included traveling to Maine and taking a supplementary short course on rural health, my perspective has broadened significantly. I’ve come to appreciate that the complexities of rural health vary widely depending on the location and community. For example, through direct interactions with patients and healthcare providers during the program, I gained insights into unique health challenges, such as injuries related to lobster fishing, the impact of drug abuse, and the prevalence of diabetes. I really enjoyed my experience shadowing clinicians to develop my capstone project with a more patient-centric view.
Student 3 (2024)	Prior to the program, I was imagining small populations with no access to healthcare technology. I didn’t realize it would be lack of healthcare professionals, transportation issues, localized health problems, etc. It was much more complex than I expected, with much more patients involved. There were problems such as transporting a patient on helicopters due to the islands or having to turn away patients and send them to a hospital 2 hours away due to the lack of a specialized doctor. After speaking to the doctors at Pen Bay, it felt like these problems could be fixed but not a lot of people have the funds or energy to try to address it. Essential technology such as ultrasound and EKG machines are greater than 10,000 dollars simply because of who sells them. Since Maine has a large elderly population, there were also problems I didn’t originally think of such as EKG tabs or bypap masks not conforming to elderly faces or skin. Additionally, at home technology also did not account for limited mobility, wrinkles, and lack of structure in face due to the loss of teeth. We could sense the frustration of the healthcare professionals in Maine, especially when they explained specialized doctors won’t want to work there because the job is more complicated due to limited resources.
Student 4 (2025)	I've gained a much clearer perspective on the disparities faced by rural communities, especially looking into the social determinants of health that are not as well protected.

Student 5 (2025)	This experience has opened my eyes to the struggles of rural America, especially when it comes to health. I believe there is much progress to be made from a policy perspective, but also ways engineers can help in the meantime.
Question 2: What were your goals or expectations of the program when you started? Were they met?	
Student 1 (2024)	I wanted the opportunity to engage with physicians and other users to develop the project that was actually needed. Yes, but I think having a more actively involved sponsor would have been helpful.
Student 2 (2024)	I initially chose to major in bioengineering and biochemistry to keep the option of medical school open through the pre-med track. Although I've since decided not to pursue that path, my passion for healthcare, disease, and the biological processes that drive them has remained strong. When I learned about the opportunity to shadow clinicians and gain insight into patient experiences, I was immediately intrigued. My primary goal was to gain exposure to healthcare settings such as the ER, ICU, and diabetes clinic. However, through the program, I gained a deeper understanding of the rural healthcare experience. Not only were my initial goals in shadowing met, but I also broadened my perspective on life in rural areas, a subject I hadn't originally considered, but ultimately found immensely valuable. I'd love to pursue more projects focused on aiding this population after my experience! Everyone I met during the program, from the clinicians to the Northeastern Faculty at the Roux Institute, were incredibly supportive in enhancing my understanding of rural healthcare. The only thing I would change would be the supporting course that was taken prior to attending Maine and catering it more towards healthcare and adding more clinical setting information for students who have never shadowed there before.
Student 3 (2024)	I wanted to be able to identify a problem, develop a solution, and have a working prototype . My expectations were beyond exceeded because my group identified three problems on the rural health trip, conducted comprehensive background research such as ANSI standards, patents, prior art, etc, made design requirements, developed 5 different prototypes, and have a final product that we are pleased with and were able to test via mechanical and signal tests.
Student 4 (2025)	My goals were to apply my engineering skills to aid rural healthcare. However, I felt that there were more problems that I was unable to solve with basic science; much of it felt administrative or based on funding. Much of the needs-finding trip were at places that didn't necessarily lack resources that were specific to rural Maine, but lacked resources that were across the whole healthcare system. I can say that if my goal were to purely test my capability to create a medical device and apply the engineering discipline to build something from scratch, I succeeded, but to say that I was truly addressing the needs of rural Maine, that goal was not fully met.
Student 5	To be honest I was not sure what I expected out of this program, but I am so glad I

(2025)	participated. I met people I would have never met, and loved this academic experience

Table A4. Sample Size of Students and Teams

Sample Size of Students and Teams			
Number of:	Individual Students	Survey Responses	Teams
2024			
Immersed	5	3	1
Involved	15	11	3
Control	57	37	12
2025			
Immersed	6	3	1
Involved	15	11	3
Control	69	36	12

Table A5. Proposed additional free response questions to add to survey.

Do you feel that your preparation prior to capstone (e.g., coursework, the immersion trip, or other experiences) equipped you to manage situations where a client's preferred solution may not align with the identified need? Why or why not?
Describe a time during your capstone project when a clinician or client expressed a preference for a specific solution. How did you respond, and how confident did you feel navigating that interaction?