The Clinical Peer Mentors Program: Student Motivations, Skills and Knowledge Acquisition, and Influence on Career Path

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Introduction

Biomedical engineering (BME) students aspiring to careers in healthcare and medical product development are better prepared when they possess a solid understanding of the clinical setting. However, industry-bound BME students have few opportunities to acquire an understanding of how clinical units operate or the challenges within that environment, nor meaningful interactions with health care providers in the space. Without this realism, BME students are unable to accurately define user needs in medical device development, something the FDA is increasingly emphasizing to improve safety and efficacy [1]. On the other hand, BME students interested in medicine rarely receive shadowing experiences at the intersection of engineering and medicine, and thus fail to witness how critical thinking, problem solving, and interprofessional collaboration can improve healthcare.

With support from the National Institutes of Health, we have created a Clinical Peer Mentors (CPM) immersion program for BME undergraduates to provide unique opportunities for students to interface with clinicians in their native environment, conduct clinical needs identification and assessment, and generate well defined capstone design projects. Moreover, CPMs share their newfound clinical knowledge to the broader BME student body by creating informational materials and services, refining their leadership and communication skills in the process. This allows increased awareness of the clinical environment and user needs for all BMEs associated with the design program.

In this paper, we report our results from an evaluation of the Clinical Peer Mentors program through Year 4 of the five-year project period. Our study seeks to 1.) Understand students' motivations for participating in and expectations of the program; 2.) Identify skills and knowledge acquired and which have proven valuable to CPMs as they enter their careers; 3) Determine how, if at all, the program influences CPM participants' career path. Data collected will be used to refine the program for the upcoming year and future direction of the program beyond that.

Methods

Clinical Peer Mentors Program Details

The CPM program is a year-long, paid internship for BME undergraduates. The majority of work is completed during 10 weeks in the summer and approximately 25 hours during the subsequent academic year. The objective of the program is to provide clinical immersion, needs identification, and need assessment opportunities to a group of approximately five students, who, in turn, support the larger BME Design Program by providing design projects, clinical reference materials, operating room access, and consulting services.

The CPM program was first launched in the Summer of 2015. Interested students are asked to submit applications that consist of their resume, transcript, and a personal statement. A faculty committee reviews applications and makes selections based on academic record and motivation for the program, with preference given to students who have previously taken the *Clinical Observation and Needs Finding* course. This course provides a small-scale clinical immersion experience where students learn observation, needs identification, and assessment skills which are readily translatable to, and critical for, the CPM program. Thus, students in the CPM program that took this course can teach the rest of the CPM cohort observation and needs identification skills. Students accepted into the program receive a stipend for their work. Beginning in 2016, one CPM from the previous year was reappointed to serve as the team leader for the following year. To date, 20 CPMs, 17 different students (three students reappointed as team leader) have participated in the program, including five that have taken the needs finding course (at least one per year). Participants have been primarily juniors and seniors, 12 female, 5 male. A breakdown can be found in Table 1.

Table 1: Participation in the CPM program by academic level and year.

	2015	**2016**	**2017**	**2018**
Rising Junior	1	0	2	3
Rising Senior	0	5	3	3
Senior (5^{th} yr)	1	0	2	0
Total CPMs	2	5	7	6

Clinical Peer Mentors' primarily focus on generating student-identified projects for the senior capstone design courses. Upon entering the program, CPMs receive HIPAA training, responsible conduct of research training, a clinical orientation on etiquette from the Anesthesiology Department, and informal workshops from the CPM team leader or faculty mentor on how to observe and identify clinical problems and needs. Their first task is to review de-identified journals and reports from the *Clinical Observation and Needs Finding* course and determine which student-identified needs might make strong design projects. Once CPMs have narrowed down the needs to 10-20, they conduct observations in the clinical units where the needs were first identified, gathering additional information so that the needs may be scoped and assessed for the design courses. During their observations, CPMs often identify new needs which they evaluate alongside the original needs from the needs finding course. Weekly meetings with the faculty mentor provide CPMs with guidance on their approach to need scoping and assessment. As many as 17 clinical departments participate in the *Clinical Observation and Needs Finding* course and CPMs may reach out to any of these departments. However, CPMs usually focus on a subset of 5-10 departments, depending on how they narrowed down the needs from the needs finding course.

CPMs also work with clinicians that have their own ideas and express interest in sponsoring a capstone senior design project. During meetings with the clinicians, CPMs learn about the clinical problem and determine whether any observations are necessary to better define the problem. They assist the clinician with preparing a project proposal for the capstone design course, making sure the scope and background is appropriate for design students unfamiliar with

the problem. Project proposals are the capstone design student's first introduction to the projects, generating enthusiasm and interest from the students prior to project selection.

In addition to design project proposals, CPMs generate other materials that benefit the larger BME student population. Based on their summer clinical immersion experiences, they prepare clinical handbooks that include common equipment, procedures, terminology, organizational structure, and physiology for a particular department. Currently, CPMs have created eight such quick reference guides that have been used by students in the *Clinical Observation and Needs Finding* course and are available to any other BME student preparing for a clinical observation (e.g. design teams). CPMs have also worked collectively to consolidate all of the clinical needs discovered through the *Clinical Observation and Needs Finding* course and the CPM program and created a Clinical Needs Database, with more than 200 needs to date accessible to BME students and organizations. To further expose BME students to medical device innovation, CPM students have created short videos from interviews with clinicians and industry professionals in the field, where they talk about their career paths and experiences in clinical needs finding and medical device design.

Furthermore, CPMs offer their services and expertise to the larger BME student population, especially those in the BME design program. To observe surgeries, the hospital requires trained chaperones to accompany novice students in the operating room (OR), reducing the burden of oversight from the surgical team. As chaperones, CPMs accompany BME students into the OR, enabling them to observe surgical procedures as part of the *Clinical Observation and Needs Finding* course or procedures related to their projects in the design courses. CPMs also volunteer as project liaisons for the capstone design projects, sharing their clinical knowledge of the projects with design teams and teaching them how to prepare questions for their first client meeting. Finally, CPMs have provided input and assisted in the outfitting of the BME 3D Fabrication Lab and project space, collecting equipment recommendations and best practices from other fabrication facilities on campus.

Assessment of the Clinical Peer Mentors Program

Four CPMs participated in in-depth interviews to better understand student experience in the Clinical Peer Mentors Program. Based on these findings, a survey was created and distributed to all past CPM participants.

A qualitative approach, consisting of interviews and a survey, was used to assess the student experience in the Clinical Peer Mentors program. Individual interviews of approximately 60 minutes in length were conducted with four current or former CPMs. Interview questions asked students to describe how they approached narrowing down needs, developed clinical handbooks and videos, identified and scoped clinical problems, and assisted clinicians with their design project proposals in order to investigate what students learned from their experience.
The interview protocol was developed through multiple iterations and included additional questions probing rationale for program participation, expectations, and career goals to elucidate the students' expectancy, values, and self-efficacy about their experiences [2, 3, 4]. Sample questions from the interview are listed in Table 2.

Table 2: Types of questions asked in the interviews

Sample Interview Questions
Explain how you and your fellow CPMs took the needs from the clinical observation course and narrowed them down to those that could be included in the BME capstone design courses.
Describe how you identified a clinical problem and scoped it for a BME design project proposal.
Describe a time you helped a clinician interested in the capstone design course prepare a proposal.
How has your participation in the CPM program influenced your perception of BME and career path?
How, if at all, has the CPM program affected your confidence to pursue your chosen career path?
Explain how you decided to participate in the CPM program. What pros and cons did you consider?
What were your goals or expectations of the program when you started? Were they met?
What did you enjoy about the CPM program? What didn't you enjoy?

The four students interviewed were all current BME undergraduates (two female, two male; two 2018 participants, one 2017 participant, one 2017 and 2018 participant). All four interview transcripts were coded by one researcher and due to the small sample size, a subset was coded by another researcher, using an inductive approach and looking for thematic agreement. Researchers converged on the codes after five iterations. The second researcher applied the same codes and identified similar themes in his transcripts. Codes to elicit student motivations and influence on career paths were based on Expectancy-value Theory [5] to examine student interest, attainment, utility, cost, and self-efficacy. Leadership codes were taken from a subset of observable outcomes identified previously for leadership, adaptability, and synthesis abilities in engineers [6]. Design skill codes were created from common steps of needs identification and assessment outlined in the BioDesign textbook [7]. Codes generated were organized into the following categories: Leadership, Design Skills, Clinical Knowledge, Other Skills/Knowledge, Student Confidence, Why Apply to CPM, Career Goals, and Expect Success. The full codebook can be found in Appendix A.

Based on codes generated from the interviews, an anonymous survey was created for distribution to all past and current CPM participants. The survey included a combination of Likert and free response questions including the same eight categories identified in the interviews. Additional questions were added to probe their current position (e.g. medical school, industry), what skills and knowledge gained from the CPM program they are applying in their current position, and their confidence to perform clinical needs finding and scoping. Due to the small population of CPMs, the survey was sent to all CPMs, past and present, including the four students interviewed, to best capture the overall effect of the program on students. However, the authors acknowledge that this could be a limitation when interpreting the data.

Results

The survey response rate was 71% (12 out of 17) and included nine female, three male, six current BME undergraduates, four currently in medical school, and two in industry – one employed as an IT application analyst for a hospital's electronic medical records system and another in product development. All four CPM cohorts were represented, Summer 2015 (two respondents), 2016 (four respondents), 2017 (four respondents), and 2018 (five respondents). Note the number of respondents from each cohort (15) is greater than the total number of respondents (12) because each cohort had one student continue as team leader from the previous year.

Student Motivations and Expectations

Students largely chose to participate in the CPM program because of the opportunities to gain experience integrating engineering and medicine, interacting with clinicians and clinical units, and alignment with their career goals. Survey results supported similar reasons reported in the interviews. Respondents reported interest in witnessing first-hand how engineering and medicine interact and playing an active role as a CPM. The prospect of advancing their career goals was another popular motivation for becoming a CPM. Regardless of whether students were interested in pursuing medicine (n=8), dentistry (n=1), medical device industry (n=5), or consulting/technical services (n=3) at the time they participated in the CPM program, many stated that conducting observations, working with clinicians and clinical units, and conducting needs assessment would help them be better prepared for their future careers. Interest in the program can also be credited to past participants, as several survey respondents mentioned having interest after hearing a former CPM speak enthusiastically about their experience. The following interview comment summarizes students' motivations for the CPM program:

> *I wanted to get more of that engineering plus medicine experience. Be in the clinic more and look for more clinical problems. Probably career choice, because I think maybe going into the medical field, this program distinguishes a student. It shows that they have a different type of clinical knowledge than just general clinical exposure. I think that was a valuable skill that I wanted to develop through the program, so that was a big factor in why I wanted to do it."*

Students noted few, if any, drawbacks to the program and expectations closely mirrored their motivations for participating in the CPM program. When asked what drawbacks, if any, students considered when making a decision about the CPM program, many stated there were none. Two respondents mentioned that they could have made more money and gained more career-specific experience if they had pursued an industry internship instead. In the survey, respondents noted they anticipated getting out of the program shadowing opportunities, collaboration with clinicians, building their professional network, and further developing needs identification, assessment, and communication skills in the context of preparing design project proposals:

> *"Exposure to needs identification and problem identification in the medical field. In addition, the connections and shadowing experience was so unique because I had clear goals of what I wanted to get out of [the] shadowing experience."*

Leadership Skills

While analyzing the interviews, four main themes of leadership skills were identified: collaboration, communication, decision-making, and disseminate knowledge to the inexperienced. These themes were included in the survey and responses were similar to those from the interviews.

CPMs demonstrate further collaboration and teamwork, building upon these skills learned in previous situations. We broadly defined collaboration as sharing and delegating responsibilities, completing tasks assigned, showing respect, and helping one another. Collaboration was evident when students described how they would narrow down the needs from the clinical observation course to generate design project proposals. In interviews, students explained how they would each be assigned to a different clinical need, department, or physician. They would collect the required information to scope the need, collectively discuss their conclusions and decide, as a group, whether to move forward:

> *"We were all assigned some needs to do prior art on. Then, to rank them, we divided it up again, to review someone else's work, so we all had standardized numbers. If we didn't agree with something, we all looked at it….Most of the research we did individually, but then we had weekly meetings where we all came together and talked about them all. Then, when we asked [the physician] to meet with us, we were all there, and he talked us through it. Then, using his expertise and our discussion, some people would go to observe whether a need was actually viable. We would synthesize all that information to decide which needs to follow through on."*

Although survey respondents indicated that they already possessed these skills prior to their involvement in the CPM program (Appendix B), they still reported strengthening these skills, as seen in Figure 1 below.

Similar responses were seen in the survey regarding decision-making skills. We defined decision-making as collecting all information, data, and input before making decisions, not rushing to a decision. In interviews, students talked about collecting market data, reviewing prior art, and collecting input from stakeholders before deciding whether a need would be feasible for the design courses. Like collaboration skills, survey respondents reported using decision-making skills in the CPM program even though they had experience with those skills prior to beginning the program (Figure 1 and Appendix B).

Conversely, students gain more experience developing their communication skills as CPMs than they have before entering the program. To identify, scope, and assess needs, the CPMs must be able to discuss engineering constraints with clinicians and explain the clinical problem to fellow CPMs, supporting his/her assessment of the need as a potential design project. Moreover, CPMs create design project proposals, clinical handbooks, and videos that must clearly explain clinical problems, clinical procedures, physiology, etc. to BME students unfamiliar with clinical settings or problems. Through these materials, they share knowledge of the clinical setting that other BME students would otherwise not be exposed to or would have a steeper learning curve upon their first experience in the clinic. In the survey, respondents largely either "strongly agreed" or "somewhat agreed" that they were able to communicate engineering concepts or clinical

problems orally or in written form to clinicians or other CPMs. Furthermore, they also reported sharing knowledge of clinical settings, problems, or need scoping with BME students unfamiliar with the clinical setting (Figure 1). These are communication skills they did not report possessing before joining the CPM program (Appendix B).

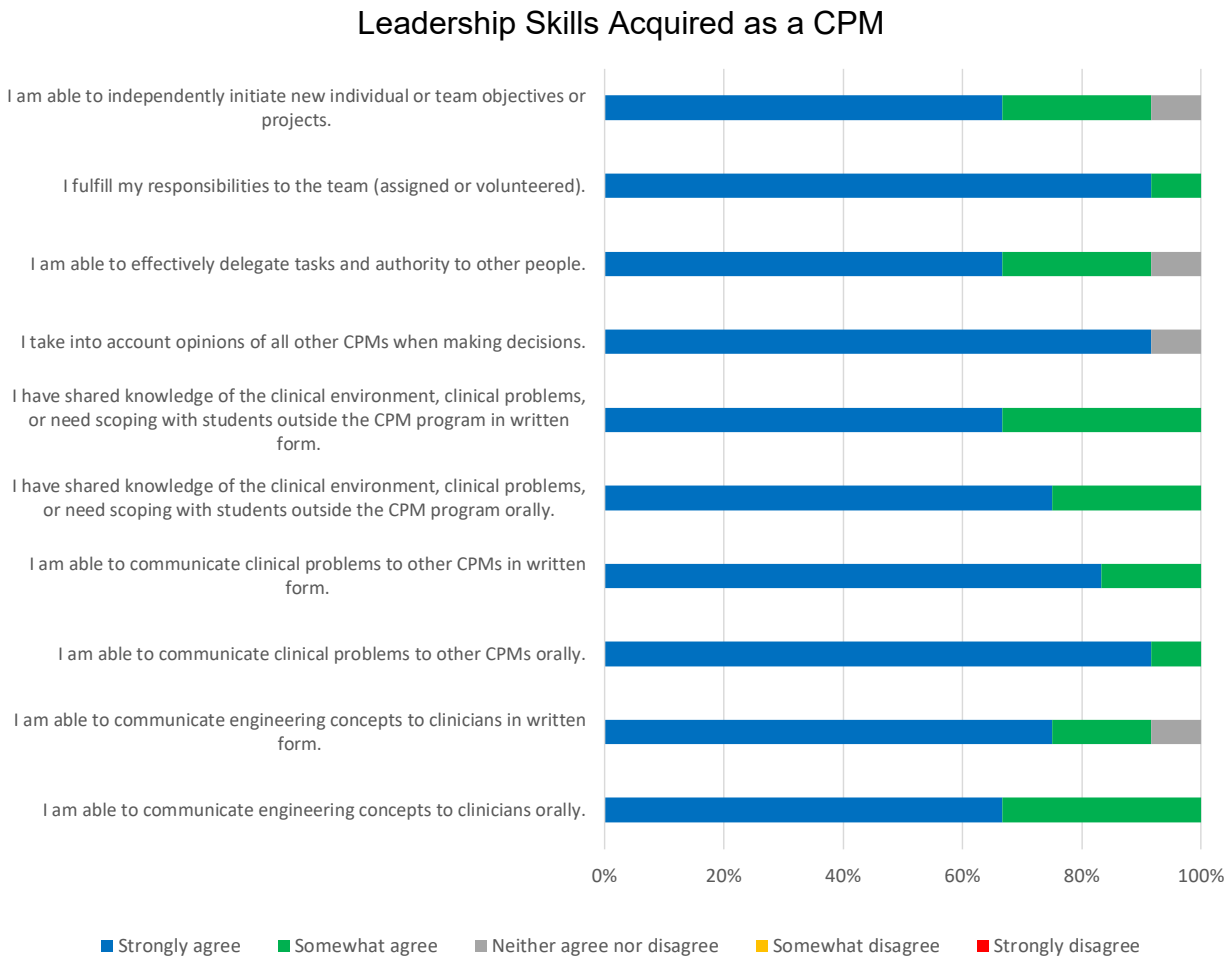

Figure 1: Survey results indicating that students utilize and strengthen their leadership skills in the CPM program.

Design Skills

As would be expected, the CPM program provides participants the opportunity to cultivate design skills, particularly those associated with needs identification and assessment related to medical products. This was confirmed by the interviews and four themes - solicit input from stakeholders, research existing solutions, define and scope needs, and evaluate needs - were defined and incorporated into the survey. Survey results indicated that these skills were fostered within the CPM program and confirmed that most CPM participants had not previously developed these skills (Figure 2, Appendix B).

Both interview and survey results suggest CPMs are able to solicit input from stakeholders, a critical early step in needs identification and scoping. Interviews revealed that CPMs learned

how to talk to clinicians, asking questions to better understand the clinical background (e.g. anatomy, pathophysiology, procedure). Most interviewees referred specifically to meetings with physicians, but a couple also mentioned the value of seeking input from nurses and maintenance workers:

> *"I think talking with them [physicians] was very helpful because it gave us a little bit of perspective of why this is actually a problem. They gave us information that you can't look up on the Internet, so that, I think, was probably the most valuable thing. They give us their first-hand experience."*

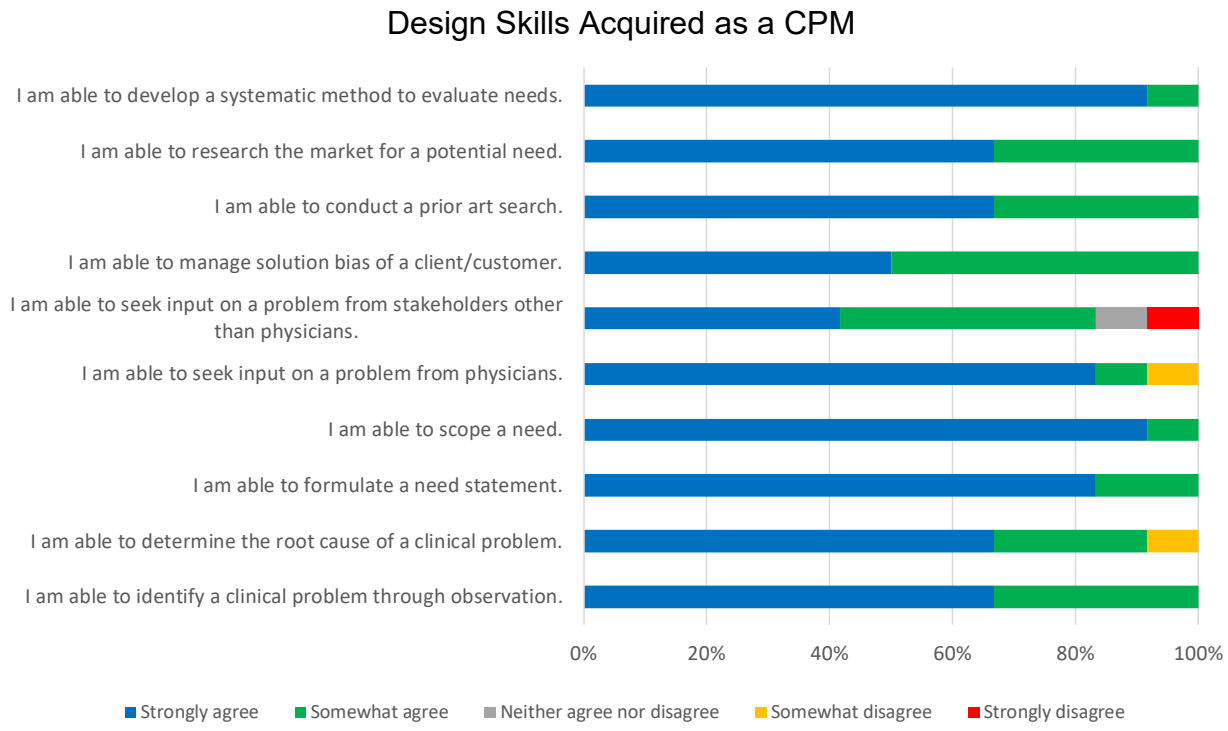

Figure 2: Survey results indicating that CPM participants develop needs identification and assessment skills.

CPMs also conducted research on existing solutions through prior art searches and market analysis. All four interviewees mentioned performing prior art searches to evaluate clinical needs for the design course. And although market analysis was only mentioned in two interviews, survey responses were all "strongly agree" or "somewhat agree" to the question, "I am able to research the market for a potential need. Before the CPM program, most survey respondents did not feel they could conduct a prior art search or market analysis (2 "strongly agree" and 3 "somewhat agree" each for prior art and market analysis).

To generate successful design project proposals, CPMs learned to define and scope clinical needs, as shown by the interviews and survey results. This required CPMs to establish the "right" problem and determine what could be addressed by BME design teams within the time constraints of the course. Again, survey results indicate few had previous experience defining and scoping needs, but after the CPM program, most felt they could. In addition, interviewees noted that they often had to dissuade solution bias of clinicians interested in sponsoring a design project:

"His problem was, I need a direct connection between the squeeze ball and maturation. Then, we re-scoped the project to be the problem was, maturation isn't happening enough, so we need a solution to fix that. That's how we re-scoped it to open it up to other potential solutions, besides his idea."

Finally, CPMs also report that they are now able to evaluate clinical needs as a result of their experience in the program. Each of the four interviewees mentioned establishing criteria and a quantitative system for evaluating their needs based on the data they collected. Survey data showed that some respondents had had some experience with need assessment prior to their involvement in the CPM program; however, after the CPM program, all students felt that they could conduct needs assessment.

Clinical Knowledge

Involvement in the CPM program improved students' understanding of medical terminology, how clinical units operate, and their organizational structure. For example, students learned medical terms, abbreviations, how rounds are conducted, and the difference between a resident and an attending physician. In surveys, respondents indicated some knowledge of medical terminology, but less of clinical operations and structure before starting the CPM program. However, after participating in clinical observations and creating clinical handbooks, CPMs either "strongly agree" or "somewhat agree" in having a broader understanding of both medical terminology and clinical operations and/or structure.

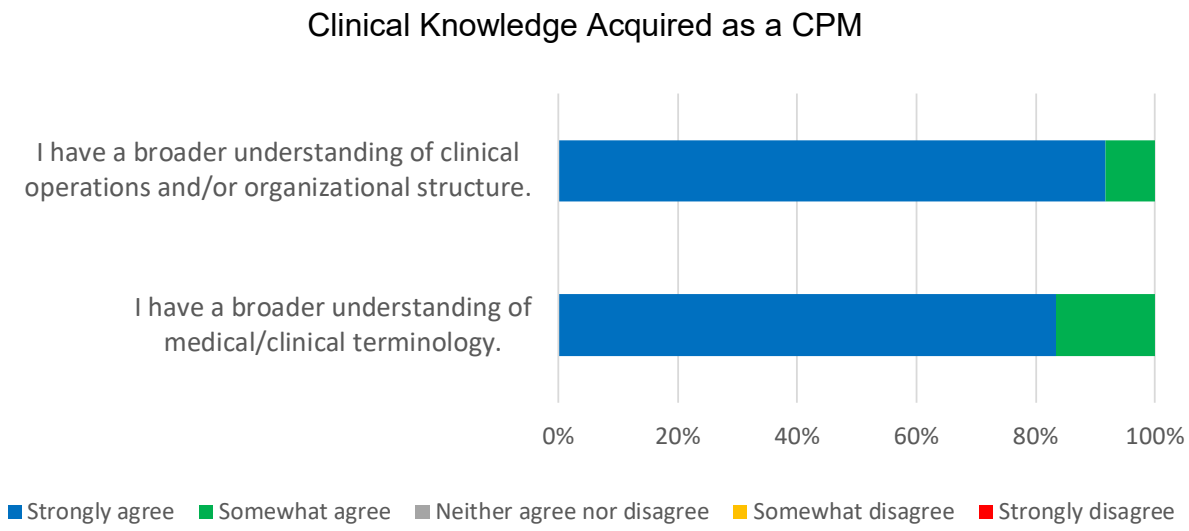

Figure 3: Survey results indicating that CPM participants have a better understanding of medical terminology, clinical operations, and the organizational structure.

Other Skills/Knowledge

The CPM program also offered students the chance to apply systems thinking, strengthen their capacity for self-learning, and better know BME faculty, staff, and operations. Although not mentioned in every interview, systems thinking and self-learning (i.e. learning how to learn what

you don't know) skills are valuable career skills and were incorporated into codes for the survey. Survey respondents indicated little systems thinking exposure, but some familiarity with self-learning prior to the CPM program. Following their experience in the CPM program, respondents indicated "strongly agree" or "somewhat agree" to being able to utilize both skills as shown in Figure 4. Unexpectedly, students in interviews and surveys stated that participation in the CPM program "increased their understanding of how the BME Department operates and/or their familiarity with faculty and staff". Most indicated they "strongly disagreed" or "somewhat disagreed" or "neither agreed nor disagreed" before they participated in the CPM program. After the CPM program, all participants either "strongly agreed" or "somewhat agreed" that they better understood the department and/or had a better familiarity with faculty and staff as stated in the following survey comment:

> *"One of the most beneficial experiences was getting to know the faculty, staff, and resources within the BME department. It was great to get to know the people behind the scenes and to give feedback in various ways throughout the summer. As a result of my CPM position I was included in many planning and feedback sessions and found myself with new leadership opportunities and visibility in the department. The CPM program was crucial to my college development and has led to many other opportunities."*

Likely, this is because CPMs were given opportunities to participate in teaching faculty interviews, work with staff (e.g. IT, facilities), and provide their input on the BME design space.

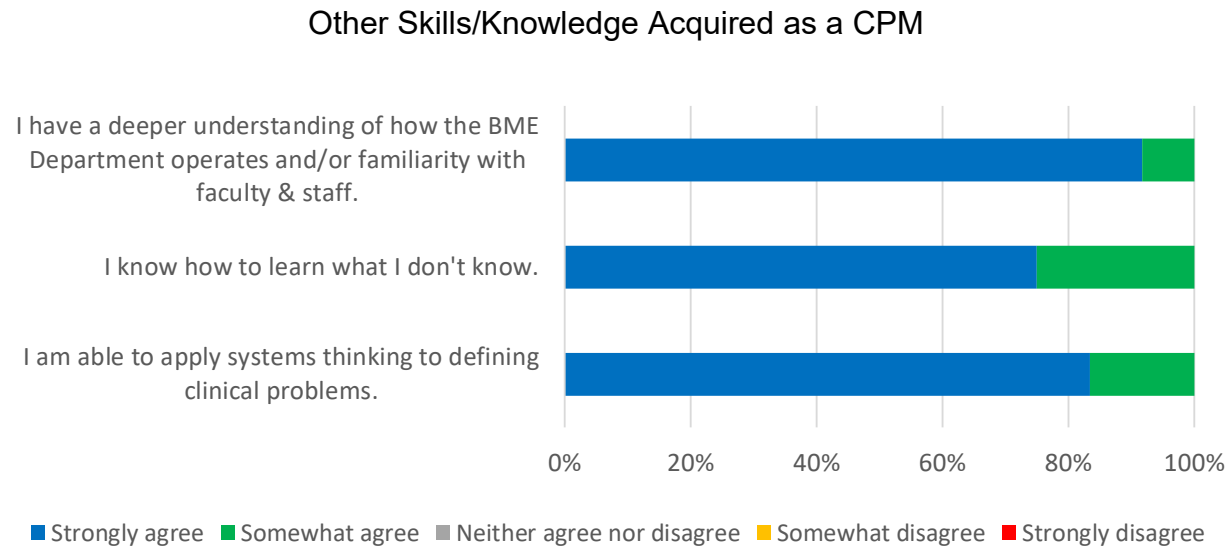

Figure 4: Survey results indicating that CPM participants feel more comfortable with applying systems thinking, self-learning and are more familiar with BME operations and/or faculty and staff.

Career Influence and Application

When asked whether participation in the CPM program influenced career paths, 66% (8/12) respondents said it did. Six students preparing for a career in medicine or dentistry stated that the CPM program showed them it was possible for health care professionals to contribute to medical device innovation and that they are interested in pursuing that path. For four participants, their experiences within the CPM program helped them discover their career path in

clinical engineering (2), product development (1), and the biomedical industry instead of medicine (1). The following remarks support these claims:

> *My experience in the CPM program did influence my career goals. I hope that when I become a physician, I will be able to address clinical needs in the department I work in by taking a step back and being able to quantitatively analyze the root cause of a problem, analyzing prior art and why it is not being used and more, to draft a clear and precise need statement. I would like to work with biomedical engineering teams to address problems that I see in the clinical side of things, so that as a team, we can work to improve healthcare for people."*

> *"Yes! The CPM program exposed me to clinical engineering, which I had little knowledge of prior. I thought I was interested in the research and design of medical devices, but I am now pursuing clinical engineering. During this program I learned that I enjoy working in the hospital environment and interacting with clinicians. In addition, the CPM program helped me gain a position in a research lab, which has been an amazing experience so far."*

Besides those identified through the initial interviews, respondents offered, in the free response portion of the survey, additional skills and knowledge gained that provide perhaps some of the best insights into the impact of the CPM program:

> *"I gained a lot of leadership and teamwork skills in a context that I was very much not used to. I'm used to having an experience-based leadership structure in which senior members of a team take the lead. The CPM program was not that. It was more democratic, and there weren't clear leaders on tasks. All of us were forced to learn how to function on a team like that."*

> *"I have become much more aware of my surroundings during clinical experiences as a medical student. As I am being told a task I am to perform, I automatically jump into thinking about the flaws, how the task can be done better, what kind of additional tools will help make this task go easier, how does this task affect the safety of the patient, etc."*

> *"I learned what skills/technologies are needed to answer certain needs within a timeframe. Currently, I work in product development and am given the responsibility of evaluating technologies/projects that are both on-going and near initiation. If I feel that there is not a large enough need or that the technologies needed to make our products succeed [are lacking], I close the projects. This lens of non-biased objectivity is something that I gained from working as a CPM."*

> *"Build confidence being able to interact with very knowledgeable people….. - gain confidence in asserting my ability as an engineer and recruiting and establishing relationships with clinical professionals by developing my communication skills."*

> *"My biggest takeaway is my critical thinking skills in design and clinical research. I am able to identify problems within research and take steps forward to drive my own research. The design process and research process have many overlaps in*

understanding how to ask the right questions and continue to collect information to find solutions. For example, I am able to initiate my own projects and use my time wisely in driving a project forward….The program taught me the professional skills and personal development such as confidence that are invaluable in pursuing clinical research and design projects."

Discussion

The findings of this study indicate that students' motivations for participating in the CPM program align closely with their interests and career goals. Many had a curiosity for clinical operations, clinicians' thoughts and behaviors, and clinical procedures. In addition, students indicated a desire to apply, or at least witness first-hand, how their biomedical engineering training could be applied to medicine. This includes needs identification and assessment, skills some students were less experienced with, but fall more generally under problem-solving, a strong engineering skill. With many CPMs interested in medicine or medical product development, they clearly view the program has having utility in helping them reach their career goals and most did not note any costs to participating in the program. In interviews, all four students stated that they expected to be successful in the program, based on their previous experiences from the needs finding course or extracurricular student organizations. With strong interest, utility, and expectation of success with low cost, it is not surprising that students choose to participate in the program, based on Expectancy-value theory [5].

The clinical immersion experience provided by the CPM program allows students to gain or strengthen skills and knowledge that prepare students for careers in medicine, healthcare, and industry. Many of the leadership skills presented in this study map well to some observable outcomes identified previously for leadership, adaptability, and synthesis abilities in engineers (e.g. clearly explaining concepts to clinicians or students, delegating tasks or authority, fulfilling responsibilities to the team, taking into account opinions of all others before making decisions, gathering as much input as you can before making decisions) [6]. Many students entering the CPM program have previous leadership and fundamental needs identification design skills acquired through extracurricular design teams, the *Clinical Observation and Needs Finding* course, or volunteering at the hospital. However, students report these skills are strengthened and expanded upon through their CPM experience. CPMs seem to enjoy the largest gains in clinical operations knowledge, clinician communication, prior art research, market analysis, and needs scoping, skills not addressed in the curriculum at the time they join the program.

One remarkable aspect of this program is how CPMs are able to share their knowledge with other students who have not had the same clinical and needs finding experiences. In one interview, a student recalled how he used his CPM knowledge of researching and scoping a problem to help first- and second- year students in a newly formed student organization, consisting of engineering and liberal arts students, approach a design project for a disabled patient. The student-generated design project proposals have allowed students in the capstone design courses a greater diversity of project options as well as more entrepreneurial opportunities, since many clinician-identified projects require students to share intellectual property with the university. This year, CPMs initiated a workshop for the design courses, providing instruction on how to communicate with clinicians about their problem and ask

questions to uncover the true unmet clinical need. The clinical handbooks and needs database are used by students enrolled in the *Clinical Observation and Needs Finding* course to prepare them for their first observation and subsequent needs identification. A couple of student organizations have expressed interest in accessing the needs database for design projects. Furthermore, students have been able to observe surgeries because a CPM accompanied them as a trained chaperone. Without the CPM chaperone, the hospital would not permit observations.

Finally, the career insights CPMs receive through the program validate their motivations for participating in the program. Nearly all of the CPMs in medical school or pre-med expressed interest in being involved in medical innovation as a physician. Those in medical school also mentioned how they view their training through the critical and analytical lens, whether that is assessing the limitations of a clinical procedure or technology and how to improve it, or what questions and data to collect in clinical research. A couple of students stated that the CPM program exposed them to clinical engineering as a career, which they are now pursuing. Another student decided to turn from a career in medicine to the BME industry and another pursued product development based on experiences in the CPM program. From these responses, it is clear the CPM program has given students a broader understanding of the career opportunities within healthcare and the medtech industry.

Conclusions

Upon completing the Clinical Peer Mentors program, students have strengthened their leadership skills and acquired new front-end design skills and clinical knowledge. They also developed a stronger sense of community within the department. In addition, the program provided them with clinical exposure, clinician interactions, and the opportunity to experience how engineering and medicine integrate. This experience provided them with a broader perspective of career paths in both medicine and medical technology innovation. Benefits of the program extend beyond the CPMs. Students within the BME Design Program received student-generated design projects, exposure to the clinical setting through clinical handbooks and operating room access, and mentorship on needs scoping and clinician interactions.

This study provides several opportunities for future work. Data from student cohorts not participating in the CPM program should be compared to CPM responses to better ascertain program impact (e.g. influence of the CPM program on career path). Furthermore, assessment of performance and/or program deliverables (e.g. design proposals, clinical handbooks) could be conducted to confirm gains in skills/knowledge. The authors would also like to investigate in more depth students' expectancies, values, and self-efficacy about their experiences in the CPM program. In addition, data in this study could allow closer examination of how students approach clinical needs identification and assessment to inform best practices in the pedagogy.

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References

[1] U.S. Food and Drug Administration. Applying Human Factors and Usability Engineering to Medical Devices: Guidance for Industry and Food and Drug Administration Staff, https://www.fda.gov/downloads/medicaldevices/.../ucm259760.pdf, Accessed 2/3/19.

[2] J. W. Creswell, *Qualitative Inquiry & Research Design: Choosing among Five Approaches, 3rd Ed.* Sage Publications, 2013.

[3] M. Patton, *Qualitative Research and Evaluation Methods, 4th Ed.* Sage Publications, 2015.

[4] J. Saldana, *Fundamentals of Qualitative Research.* Oxford University Press, 2011.

[5] J. Eccles, "Who Am I and What Am I Going to Do With My Life? Personal and Collective Identities as Motivators of Action," Educational Psychologist, 44(2), pp. 78-89, 2009.

[6] B. Ahn, M. F. Cox, J. London, O. Cekic, and J. Zhu, "Creating an Instrument to Measure Leadership, Change, and Synthesis in Engineering Undergraduates," *Journal of Engineering Education*, vol. 103, no. 1, pp. 115–136, January 2014

[7] P. G. Yock, S. Zenios, J. Makower, T. J. Brinton, U. N. Kumar, F. T. J. Watkins, L. Denend, T. M. Krummel, C. Q. Kurihara, *BioDesign The Process of Innovating Medical Technologies, 2nd Ed.* Cambridge University Press, 2018.

Appendix A

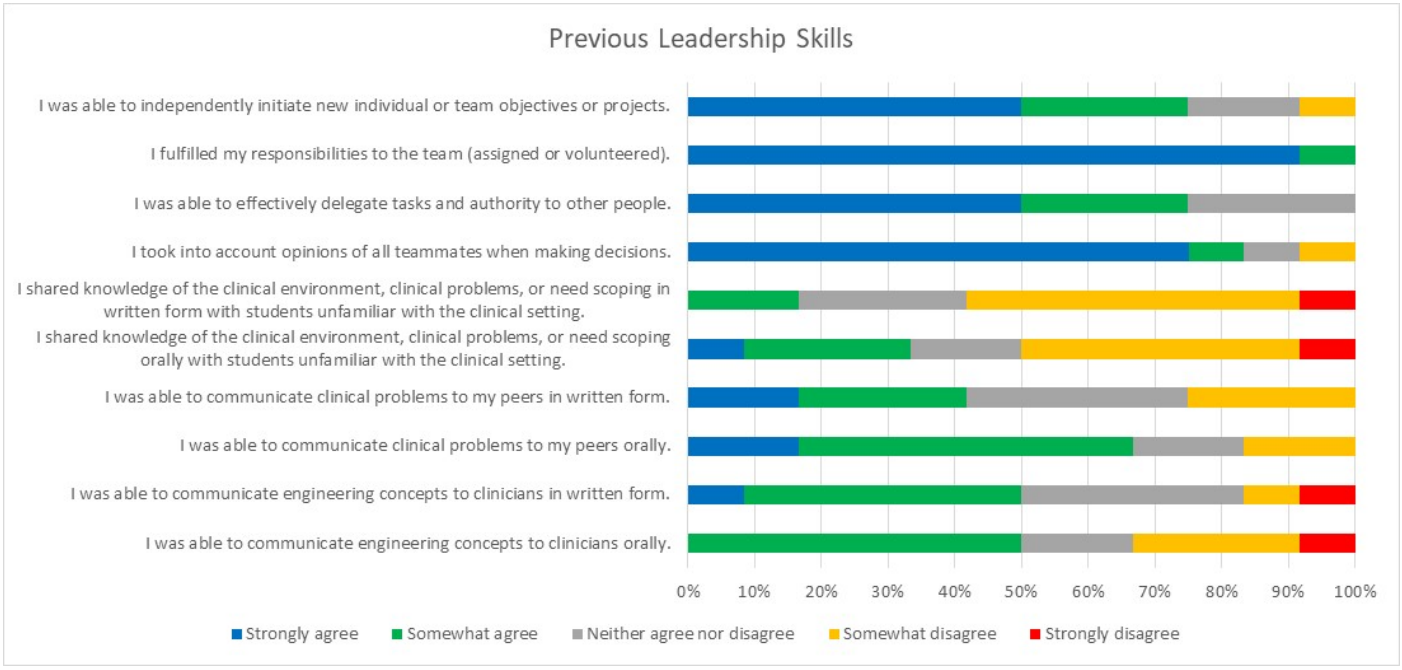
Clinical Peer Mentor Program (CPM) Interview Codes

Leadership	Design Skills	Clinical Knowledge	Other Skills/Knowledge	Student Confidence	Why Apply to CPM	Career goals	Expect Success
Collaboration	Solicit input from stakeholder	Medical/clinical terminology	Systems thinking	Intimidated by or defered to clinician	Applying BME to medicine	Medicine	Yes
Commmunication	Research existing solutions	Clinical operations and/or organizational structure	Self-learning	Unsure of role/expectations with clinicians or clinical unit	Experience with clinicians or clinical units	Industry	No
Decision making	Define and scope problem/need		BME operations, faculty, and/or staff	Gained confidence/comfort with clinician or clinical unit	Professional development	Medical device innovation	Not sure what defined success
Disseminate knowledge to inexperienced	Evaluate problems/needs						

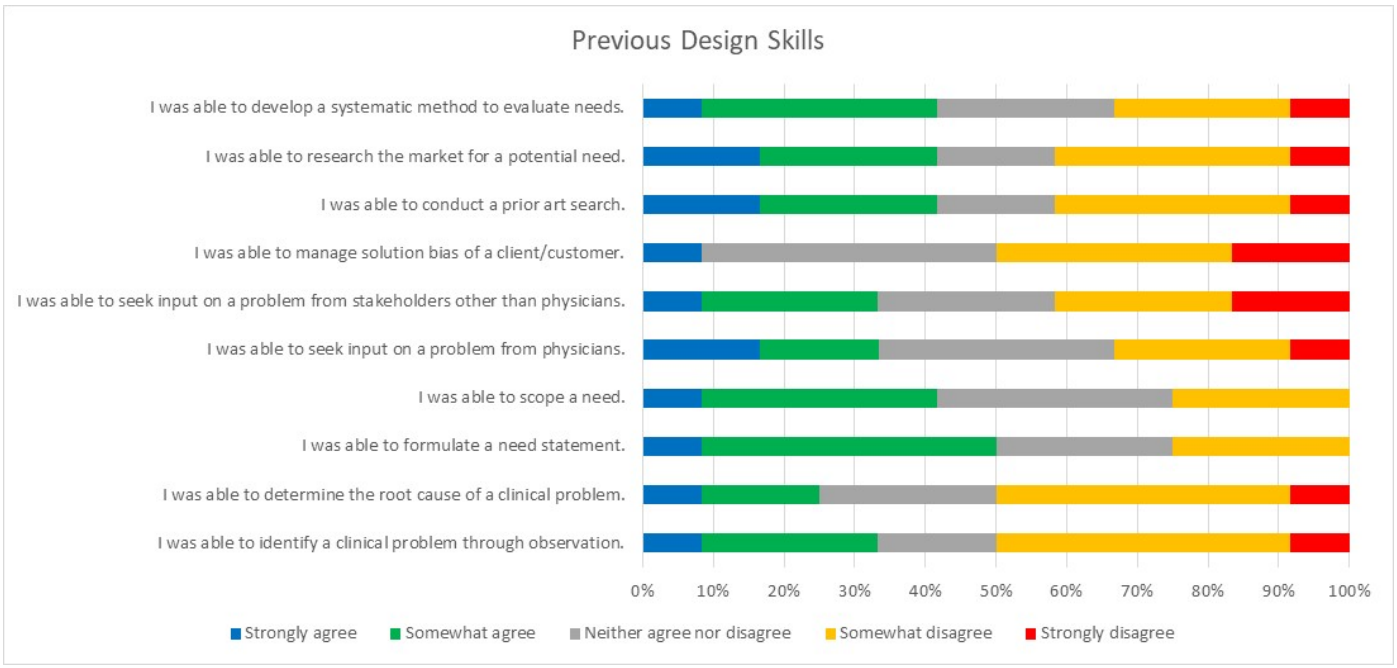
Appendix B: Survey Responses

Previous Skills and Knowledge

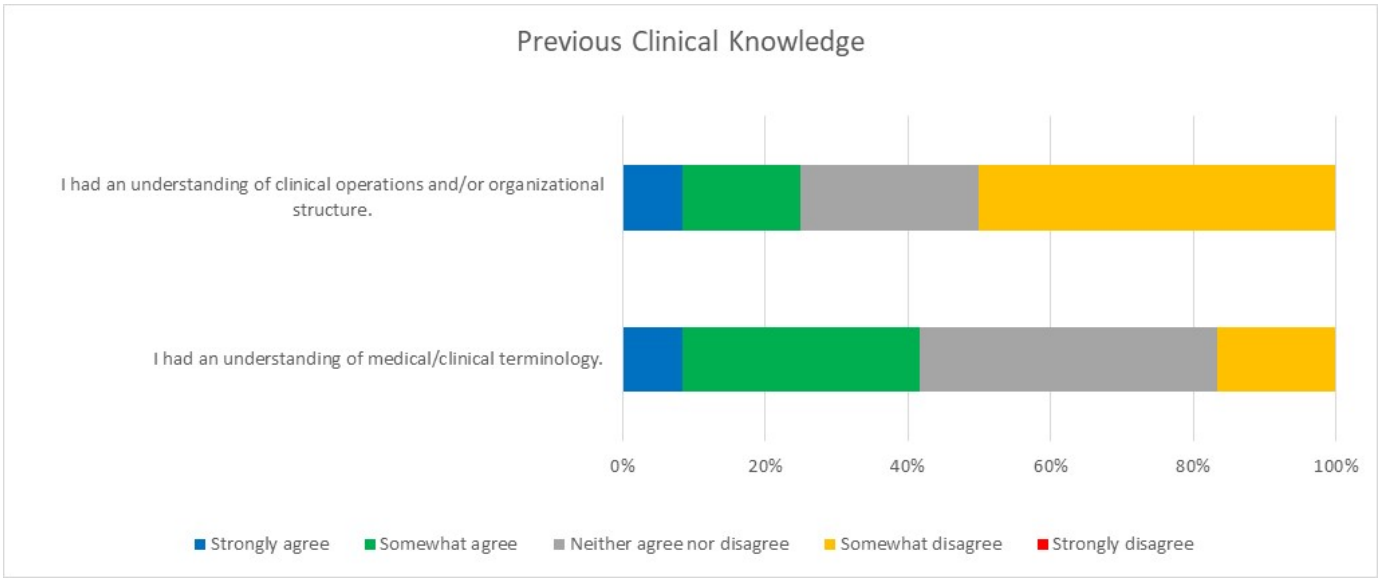
Please indicate your agreement to the following statements. PRIOR to my participation in the CPM program.....



Please indicate your agreement to the following statements. PRIOR to my participation in the CPM program.....



Please indicate your agreement to the following statements. PRIOR to my participation in the CPM program.....



Please indicate your agreement to the following statements. PRIOR to my participation in the CPM program.....