The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #41944

Mentoring for Making: Peer Mentors Working with Learners in a Making-Focused Engineering Course

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Introduction

Peer mentoring in college programs of study is not uncommon. However, most of the time, peer mentoring is focused on supporting students in traditional solving problems they are assigned as part of the coursework. Our work extends beyond examining conventional forms of peer mentoring by examining the work of peer mentors supporting students' work in a first-year engineering design course based in a makerspace classroom. The problems students solve in the makerspace classroom-based course typically have a wide array of possible solutions, which differs from many problems students solve in traditional courses with peer mentor support. Further, students in the makerspace classroom-based course are also expected to work in teams, which adds another layer of complexity to the role of the peer mentors working in the course.

Review of Literature

Social Skills

Social skills are critical for the success of professional engineers [1, 2]. Because the development and expressions of social skills are likely to vary widely among engineering students [2], there is a benefit to creating opportunities for students to develop and refine their skills. A potential ideal environment for teaching and developing social skills is laboratory situations in which students collaborate as they work in teams [3, 4].

Students are much more likely to experience positive growth in their social skills when those they seek support from when learning (e.g., faculty members, and mentors) integrate and model effective social skills in their interactions [5]. Thus, there is justification for researching the students' awareness and understanding of the social skills modeled for them in their interactions with their learning leaders. Specific to our research, we wanted to know what social skills the students perceived were being modeled by the peer mentors working in a makerspace classroom.

Technical Skills

The role of an engineer can vary widely, and as a result, the technical skills required by those in engineering roles may also vary [6]. For example, an engineer may be in a small start-up company or working independently and may be positioned to be engaged in processes from the initial idea, drafting solutions, creating models, testing prototypes, and refining potential end products. In contrast, an engineer may be in a large corporate organization, where their responsibilities are frequently limited to drafting plans for prototypes or products to certain specifications with minimal engagement in applying skills beyond design [7]. Yet, many engineers may want to explore diverse professional opportunities, including positions requiring diverse technical skills.

Thus, there is justification for attending to engineering majors' technical skill knowledge development in their undergraduate education. Pertinent to our research was our desire to document how peer mentors working in the makerspace classroom impacted the technical skill development of undergraduate students enrolled in a first-year design course.

Teamwork

Working in teams effectively is a fundamental skill of engineering professionals [8]. To be effective, engineers need to be able to listen, share, collaborate, engage, discuss, and resolve conflict with other team members [8]. Thus, working in teams is essential to the work of engineers [9] and is a skill students need to develop as part of their engineering education programs.

Given the importance of teamwork in engineering, engineering students must develop related skills in various settings [9, 10]. Of interest to us was how they created these skills as they collaborated on projects in an undergraduate first-year design course with the facilitation of a peer mentor.

Confidence

Students need to develop their confidence so they can comfortably move outside of their comfort zones when faced with situations of uncertainty [11, 12]. Learning and exploring new ideas frequently involves engaging in conditions of uncertainty. Progress in engineering is fraught with uncertainty as new avenues of solutions are explored and tested, which further reinforces the need to ensure students are educated in ways that build confidence and their tolerance of uncertainty [13, 14, 15].

As we considered the interactions between and among the peer mentors and the students enrolled in a first-year engineering design course in a makerspace classroom, we wondered how the interactions might influence student confidence development. In particular, if the students perceived the peer mentors to affect their confidence development and ability to acquire and apply new knowledge and skills.

Belonging

As with almost all professions, belonging is a significant indicator of students’ consideration and persistence in engineering [16]. Belonging is a complex and multifaceted variable influenced by various factors [17, 18]. Yet, belonging is critical to developing and internalizing a professional identity [16, 19]. Thus, if students feel they belong, are welcomed, and are valued in the spaces, classes, and people associated with a profession, they are likelier to pursue and persist in the profession [16]. As the students continue, they develop their professional identity, which is critical to engaging and succeeding as engineers.

We were interested in how peer mentors working in a makerspace classroom facilitating engineering students' work on design projects might influence students’ sense of belonging. In particular, how interacting with peer mentors might enhance the students' sense of belonging in the makerspace classroom.

Method

Research Question

Our overarching research question was, "How are peer mentors impacting undergraduate engineering student development in their support of learning within a makerspace classroom?" To guide our investigation, we developed the following researchable questions:

- How do peer mentors influence engineering students' social skill development?
- How do peer mentors influence engineering students' technical skill development?
- How do peer mentors influence engineering students' ability to engage in teamwork effectively?
- How do peer mentors influence engineering students' confidence development?
- How do peer mentors influence engineering students' sense of belonging in engineering learning spaces?

Participants

The intended audience of the peer mentor efforts in an Engineering Design & Society maker space-based course were the first and second-year students. To focus on the impact of peer mentoring, we examined data gathered from 341 first- and second-year students who were willing to allow their responses to be used in our study. The sample of 341 was composed of 79% first-year students and 21% second-year students. The self-reported gender of participating students was 65% male, 31% female, and 4% as a collective of other/non-binary/prefer not to answer. Students participating were from a range of academic majors, including Ag/Biological Eng., Aerospace Eng., Biomedical Eng., Chemical Eng., Civil/Coastal Eng., Computer Eng., Computer Science, Electrical Eng., Environmental Eng. Industrial & Systems Eng., Materials Science & Eng., Mechanical Eng., Nuclear Eng., Exploratory/Undecided Eng., Other/Non-Engineering. The largest percentages came from computer science (33%), computer engineering (15%), and mechanical engineering (11%).

Methodology

We used a cross-sectional survey methodology, gathering data from the engineering students at one point in time. We selected this methodology because the peer mentors interact with a large number of students. Gathering data to document the experiences and perspectives of a large number of students in a relatively short period of time necessitated using a survey. We gathered our cross-sectional data collection at the end of the semester due to the desire to gain a deeper understanding based on their reflections of their interactions with the peer mentors.

Survey

Given our research's unique focus, we determined it was necessary to develop a survey aligned explicitly with our research questions. We included both selected and open-ended response prompts to gather a combination of both qualitative and quantitative data. Our survey included free-response prompts such as, “Please share how the peer mentors made you feel the makerspace classroom is for you” “Please share how the peer mentors helped or could have helped your team work together” and “Please share how the peer mentors helped you develop confidence when working in the makerspace classroom.” We also included companion selected-response prompts such as, “Please share your level of interaction with the course peer mentors” “The peer mentors helped our team work together” and, “In this course I learned social skills are important in engineering.” We had a total of six selected-response items and seven free-response prompts.

We had four experts in engineering education and undergraduate student professional preparation review our survey for clarity and alignment with our research questions. Based on their feedback, we made minor modifications to our items to ensure clarity and consistency with our research goals.

Data Collection

To gather data from the students in the course, we appended our survey items to their end-of-semester course evaluation survey. The process of appending the items to the end-of-semester survey allowed us to contact all students in the course with the invitation to participate voluntarily in our research project and complete our survey as we distributed to them the end-of-course evaluations. Note that the university’s Institutional Review Board reviewed and approved this process. We gathered data during the final week of the semester, inviting all students enrolled in the course to participate.

Data Analysis

Quantitative Data

To analyze our quantitative data, we created a graph to display the distribution of responses and examined the data descriptively. We created a graph for each of our six selected response items. We examined the graphs for response trends that would reflect the level to which the students agreed with each statement.

Qualitative Data

We analyzed our qualitative data by coding the participants' responses using codes we generated based on each prompt theme (see Table 1). We created these a priori codes through conversations with each other and considering the range of possible responses. We anticipated our lists of theme-aligned codes would not be comprehensive; therefore, we remained open to adding additional codes as they emerged from the data analysis.

Table 1

A Priori and Emergent Codes Aligned with each Free-Response Survey Prompt and Theme

Free-Response Survey Prompt and Theme	A Priori and Emergent Codes
Please share how the peer mentors made you feel the makerspace classroom is for you. (Belonging)	Supportive / Helpful, Talked to me, Acknowledged me, Kindness / nice, Thoughtful, Friendly, Facilitated my learning, Welcomed/answered questions, N/A
Please share how the peer mentors helped or could have helped your team work together. (Teamwork)	Communication/ facilitation, Sharing roles, Conflict resolution, Talked to all of us, Gave us examples, Helpful/ accessible when needed, Nothing, Facilitated teamwork, Facilitated idea generation, Help not needed- team worked well, Check-in with groups, N/A
Please share how the peer mentors helped you develop confidence when working in the makerspace classroom. (Confidence)	Reassured Me, Gave me compliments, Work through problems with me, Gave me extra time, Provided direction /support, Encouragement, Welcoming, Kind, Let students try first/ fostered learning, Helpful, N/A
Please share what new technical skills you learned in this course. (Technical Skills)	Programming /coding, Writing, Presentation skills, Soldering, Tool use, Drafting, 3D printing, Prototyping, Other, Circuits, N/A
How did the peer mentors help you learn new technical skills? Please share. (Technical Skills)	Demonstration, Guide to websites, Coaching, Provided examples, Asked questions, Explanations, Available, Approachable, Knowledgeable, No help
Please share what engineering social skills you learned through this course. (Social Skills)	Listening, talking, Writing, Proper language, Difference in people, Collaboration, Diversity, Cooperation, Leadership, Time management, Tenacity, Observation, Problem-solving, Work together /team, Oral communication, Sharing ideas, Writing, Presentation skills, Technical language, Step by step explanations, Conflict resolution, Ethics, Original thinking, Ask for help, Delegate tasks, N/A
How did the peer mentors help you develop engineering social skills? Please share. (Social Skills)	Demonstration / Role model, Asking Questions, Listening, Facilitating discussions/collaboration, Welcoming /friendly, Think like an engineer, Gave Advice /feedback, Gave explanations, N/A, No interaction, No Help

Once we generated the a priori codes, we collectively coded a small subset of data for each theme. We then individually coded a small subset for each theme and compared the consistency of our responses. We established a Cohen's Kappa of .91, indicating high intercoder reliability.

The intercoder reliability allowed one of the team members to complete the coding individually with a checkpoint for consistency halfway through the data coding process.

We determined the need to code only the first 200 responses for each prompt, as we imagined that the amount of data would be sufficient to achieve saturation and representation of the data set as a whole.

Trustworthiness

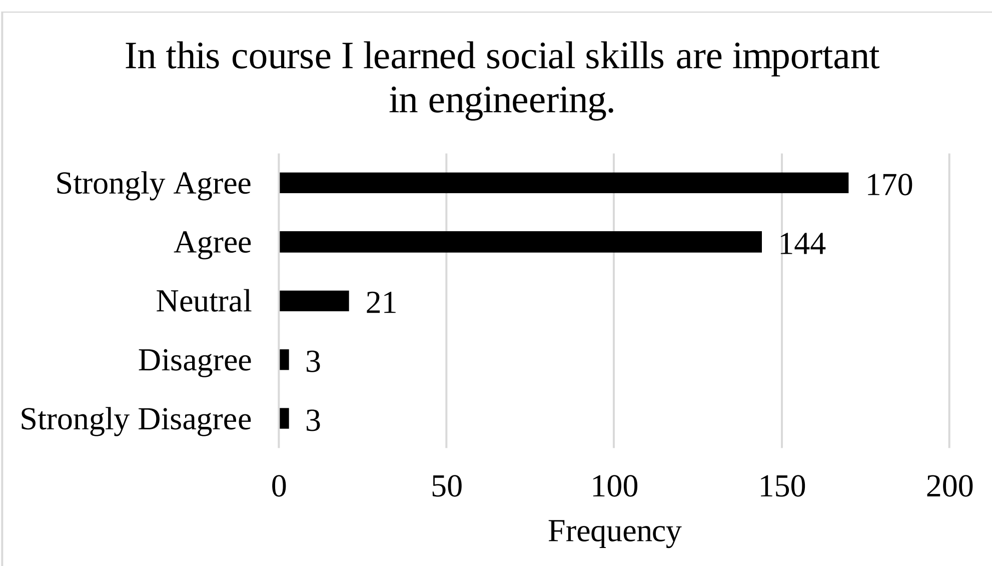
We took multiple steps to establish the trustworthiness of our research. First, we created the a priori codes as a team to ensure alignment with the research questions and consistency in data analysis, which increased the transferability of our research. We then calculated a Cohen's Kappa of .91, which reflects an acceptable level of intercoder reliability and increased our confidence in our data analysis, increasing the dependability of our results. We developed the survey collectively to increase the reliability of our tool in alignment with our research questions, increasing the credibility of our study. The survey also increases the opportunity for the transferability of our research, further enhancing our process's trustworthiness.

Results

Social Skills

Our first guiding research question asked: How do peer mentors influence engineering students' social skill development? To answer this question, we examined the outcome of our quantitative data associated with the related survey item and the coding of our associated qualitative items. Our quantitative analysis revealed that the students overwhelmingly agreed to strongly agree that they learned social skills in the makerspace classroom-based design course (See Figure 1).

Figure 1
Likert Scale Responses to Learning Social Skills (N = 341)



Our qualitative analysis revealed the participants learned multiple teamwork skills, including oral communication, collaboration, delegating tasks, and sharing ideas (see Table 2). The representative responses emphasize teamwork activities for reinforcing social skill development.

Table 2

Five Most Frequent Codes, Frequency, and Representative Responses for Acquired Social Skills (N = 200)

Code	N	Representative Response
Work Together /team	93	Throughout the course, relying on teamwork with the final project built my communication and delegation skills in terms of deciding a role to give myself when working with others.
Oral Communication	76	I learned that communication within a group is very important to be able to make sure that the project is progressing and that everyone is doing their part.
Collaboration	28	I learned how to collaborate effectively with my teammates to create a final project. I learned the communication is of utmost importance, as if there is a disconnect, it is going to cause delays in the final product.
Delegate tasks	22	Coordinating meets and dividing work for projects so we're all working concurrently
Share ideas	17	Throughout the design process in this course, communicating plans and ideas are essential to making progress in the project.

In our continued analysis we found the students in the course indicated an array of ways in which the peer mentors facilitated their social skill development (see Table 3). For example, about eight percent of the students indicated that the mentors helped them to start thinking like an engineer, which is a critical social skill when working as an engineer. Notably, almost ten percent of the students did not perceive the mentors as influencing their social skill development. Multiple students indicated that the peer mentors modeled being welcoming and friendly, which are critical social skills when working with an array of people.

Table 3

Five Most Frequent Codes, Frequency, and Representative Responses for How Peer Mentors Supported Acquiring Social Skills (N = 200)

Code	N	Representative Response
Facilitating discussions / collaboration	45	Peer mentors helped develop these social skills by having conversations with me and my team or creating discussions for us to have with one another.
Gave Advice/feedback	20	Peers could provide feedback during class that helped to look at new perspectives or solve problems the team was having during

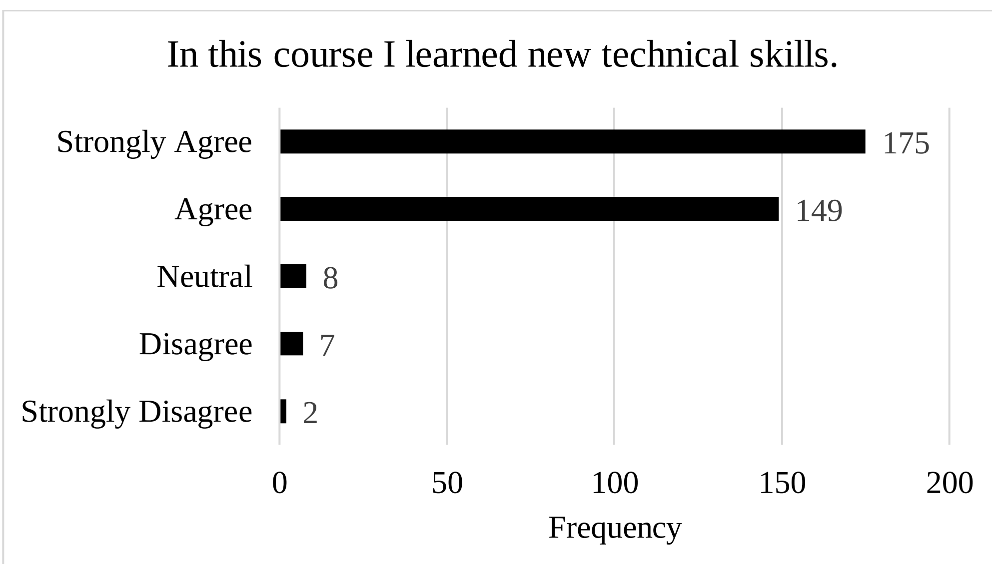
		class
No Help	19	The peer mentors were not an intrinsic part of developing my engineering social skills.
Think like an engineer	16	The peer mentors helped me develop engineering social skills by fostering a comfortable environment for asking for help. This helped me to overcome feelings of embarrassment when I needed advice on completing project components.
Welcoming / Friendly	14	They talked to us and promoted a friendly environment among our group.

Technical Skills

Our second guiding research question asked: How do peer mentors influence engineering students' technical skill development? To answer this question, we examined the outcome of our quantitative data associated with the related survey item and the coding of our associated qualitative items. Our quantitative analysis revealed the students overwhelmingly agreed or strongly agreed that they learned new technical skills in the course (see Figure 2).

Figure 2

Likert Scale Responses to Learning Technical Skills (N = 341)



In the students sharing what technical skills they learned, their primary focus was on circuits and programming or coding (see Table 4). A large percentage of the students also indicated they learned more about 3D printing and drafting. The participants infrequently shared (e.g., once or twice in the entire data set) a few of the skills they learned. Thus, we grouped these infrequently shared skills into an "other" category, which occurred in less than ten percent of the responses.

Table 4

Five Most Frequent Codes, Frequency, and Representative Responses for Acquiring Technical Skills (N = 200)

Code	**N**	**Representative Response**
Circuits	103	I learned how to build circuits on an actual breadboard. I learned how to logic my way through circuitry and take the initiative of building things myself.
Programming / coding	84	Block coding, basic 3D modeling software, basic circuits stuff. I feel like it will be a great baseline for future classes
3D Printing	76	I learned how to use tinkercad and the 3D printing software.
Drafting	47	I learned how to use onshape and build a circuit.
Other	18	Soldering and other skills.

In our analysis of how the peer mentors were influential, we found that they provided explanations, shared their knowledge, and coached the students through technical processes (see Table 5). About fourteen percent of the students indicated that the peer mentors were of no help, which could have been due to many factors, including the students not asking the mentors for help. Our data suggests that the peer mentors tended to make themselves available and accessible to the students.

Table 5

Five Most Frequent Codes, Frequency, and Representative Responses for How Peer Mentors Helped the Students Acquire Technical Skills (N = 200)

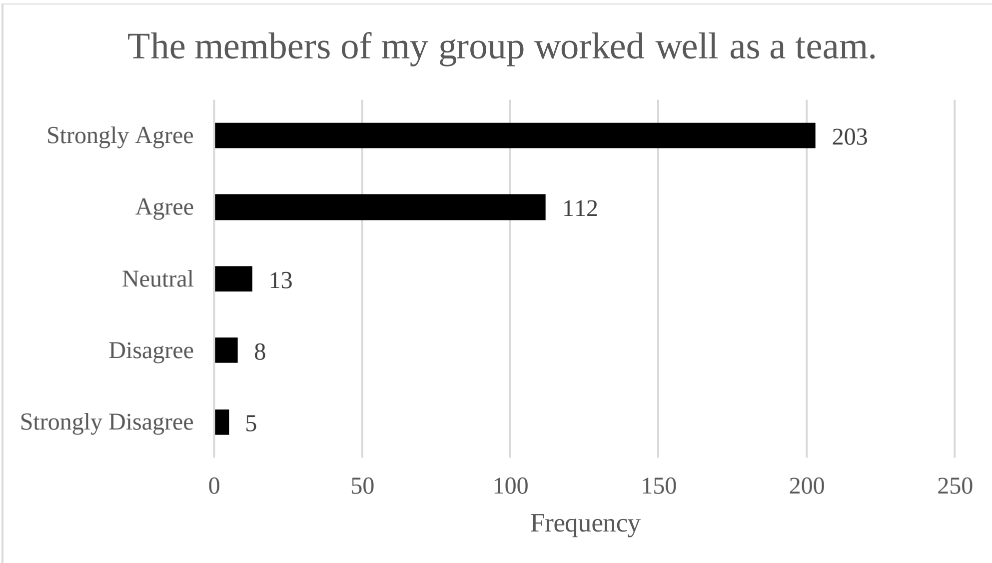
Code	**N**	**Representative Responses**
Explanations	62	Explained what they were doing when performing a task like getting models ready to print
Knowledgeable	43	When I had questions on anything technical, they were there to help. Since they had a good amount of knowledge on the technical things we went over in the class, they were very helpful.
Coaching	40	They taught me step by step.
No help	27	I never talked to them.
Available	21	The peer mentors helped me to learn new technical skills by offering demos and assistance during the peer mentor office hours.

Teamwork

Our third guiding research question asked, How are peer mentors influencing engineering students' ability to engage in teamwork effectively? To answer this question, we examined the outcome of our quantitative data associated with the related survey item and the coding of our associated qualitative items. Our quantitative analysis revealed the majority of students tended to agree or strongly agree they were in a team that worked well together (see Figure 3).

Figure 3

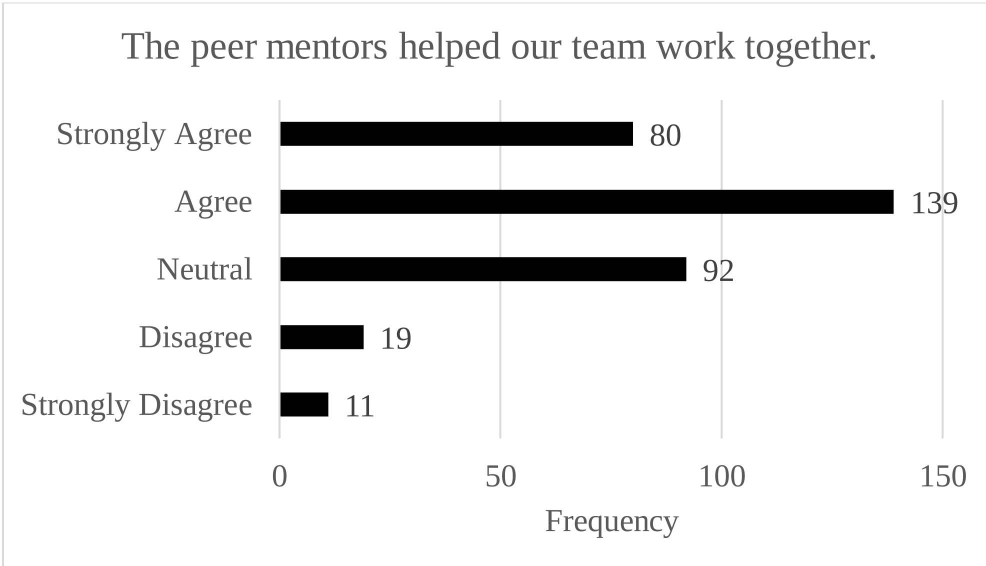
Likert Scale Responses to Working Well as a Team (N = 341)



Unlike the perceptions of students being in teams that worked well together, the students were more tentative in how the peer mentors supported their team effectiveness (see Figure 4). The participants were less in agreement with the statement that the peers helped their team, which may be due to the team already functioning well or due to limited or the lack of engagement of the peer mentors in supporting the students' positive team dynamics.

Figure 4

Likert Scale Responses to Peer Mentors Helping Teams Work Well (N = 341)



An examination of the coded data (see Table 6) revealed that the students perceived the peer mentors as helpful in supporting their team's functioning by being accessible and acting as facilitators. Yet, consistent with the quantitative data, the students' responses to the prompt indicated they did not need support from the peer mentors or perceived mentor support was not present.

Table 6

Five Most Frequent Codes, Frequency, and Representative Responses for How Peer Mentors Helped Student Teams Work Together (N = 200)

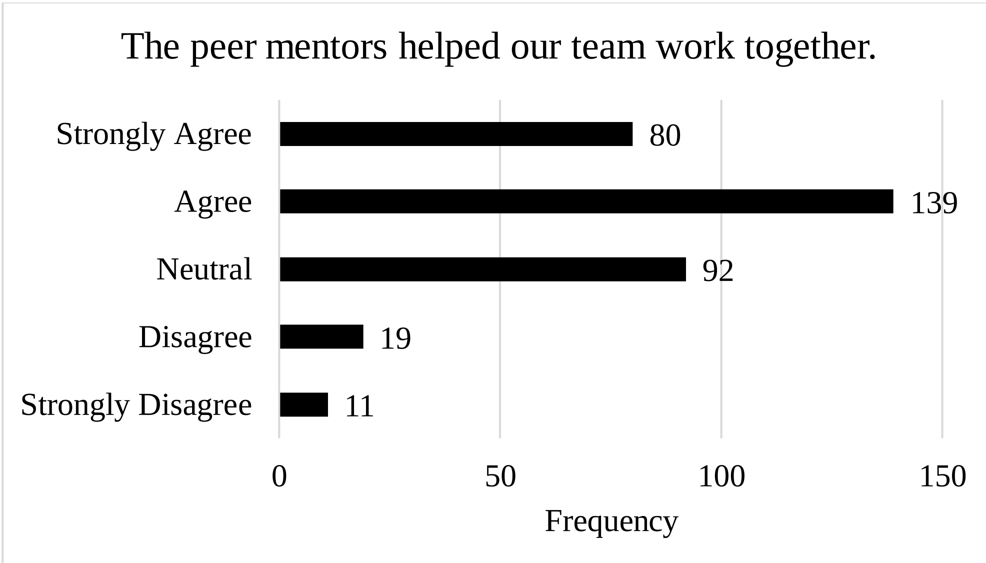
Code	N	Representative Response
Helpful/ accessible when needed	96	The peer mentors answered our questions when we needed help.
Facilitate Teamwork	27	When we came to a roadblock as a team, peer mentors were able to guide us through them with helpful knowledge and tips to work together and figure them out.
Facilitated idea generation	25	They listened to what ideas we had and gave their input.
help not needed-team worked well	23	Not much interaction was had. Not to their fault, they helped those that needed it.
Nothing	18	I feel as if the peer mentors didn't have that much effect on our team cohesion

Confidence

Our fourth guiding research question asked, How do peer mentors influence engineering students' confidence development? To answer this question, we examined the outcome of our quantitative data associated with the related survey item and the coding of our associated qualitative items (see Figure 5). Our quantitative analysis revealed that, in general, the students tended to agree that peer mentors helped them develop confidence. However, about 20% of the students indicated they were neutral or disagreed with the statement that the peer mentors helped with their confidence development.

Figure 5

Likert Scale Responses to How Peer Mentors Supported Confidence Development (N = 341)



Our qualitative data provide insight into how the peer mentors helped the students develop confidence in their engineering skills (see Table 7). The responses indicate the students benefited from receiving directions from the mentors, from general support the mentors provided, having the mentors provide the students the space to try to solve their own problems, the mentors fostering or facilitating the students' learning, and being kind to the students. Thus, the peer mentors' social skills and awareness of effectively supporting the students' learning impacted the students' confidence development. The peer mentors' dispositions seem fundamental to their effectiveness and impact on student confidence development.

Table 7

Five Most Frequent Codes, Frequency, and Representative Responses for How Peer Mentors Helped Students Develop Confidence in Engineering Skills (N = 200)

Code	N	Representative Response
Provided directions	64	They were very constructive and often gave positive feedback about our ideas.
General Help	55	Helped us with 3D printing coding and anything else we were unfamiliar with
Let students try first/ Fostered learning	17	The peer mentors let me problem solve by myself but also were ready to step in to help with anything I needed especially with issues working with the wiring of the Arduino.

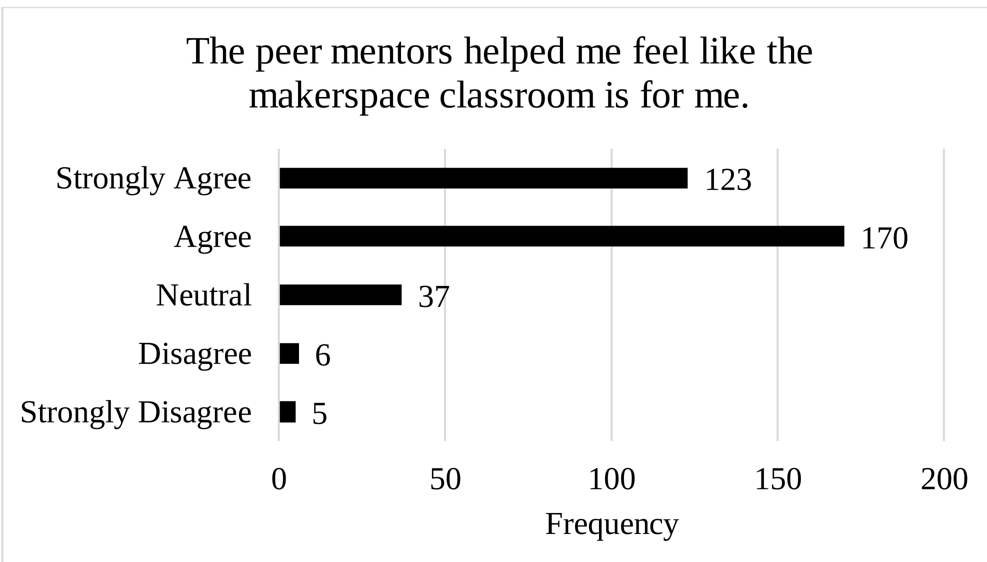
Kind	15	You could ask them any question without them being judgmental.
Work Through Problems with me	13	They didn't just fix the code or circuits themselves so that they would work, but they also explained what went wrong and showed us how to fix it so we wouldn't make the same errors in the future.

Belonging

Our fifth guiding research question asked, How are peer mentors influencing engineering students' sense of belonging in engineering learning spaces? To answer this question, we examined the outcome of our quantitative data associated with the related survey item and the coding of our associated qualitative items. Our quantitative analysis revealed the majority of the students agreed or strongly agreed that the peer mentors helped them feel like they belonged in the makerspace classroom (see Figure 6).

Figure 6

Likert Scale Responses to Peer Mentors' Fostering Belonging (N = 341)



In our analysis of the students' free response items, we gained insight into how the peer mentors may have influenced their sense of belonging in the makerspace classroom (see Table 8). We found the students' responses to how the peer mentors made them feel like they belonged in the makerspace classroom overlapped considerably with their responses to how the peer mentors supported their confidence development. The participants shared the mentors were helpful, kind, welcoming, friendly, and facilitated their learning. Again, the mentors' dispositions seem to have played a role in substantially impacting the development of the students they mentored.

Table 8

Five Most Frequent Codes, Frequency, and Representative Responses for How Peer Mentors Supported Students' Sense of Belonging (N = 200)

Code	N	Representative Response
Supportive / Helpful	110	They were always available for questions and gave extremely helpful advice.
Facilitated My Learning	62	Whenever I asked for help they guided me through the problem with tools in the classroom rather than just solving the problem for me.
Kindness / Nice	27	They were very kind and open to helping, they seemed genuinely interested in what we were working on/why we made certain decisions in class activities/etc.
Welcomed/ Answered questions	27	They made me feel like I could ask anything and they were very helpful in answering questions and were very knowledgeable
Friendly	22	The peer mentors were extremely friendly, always willing to help, and made time for you to talk one-on-one.

Discussion and Implications

Our research goal was to explore how peer mentors working with students in first-year design courses that took place in a maker-space classroom impacted the students' learning and development. We found that the mentors' actions, knowledge, communication, and dispositions substantially influenced multiple facets of student development and learning in a makerspace classroom.

We anticipated the mentors' knowledge would be widely recognized as impacting the students' development and success in the course. However, we did not anticipate the substantial and critical role of the mentors' dispositions in supporting the students they were mentoring. The awareness of the substantial impact of mentor dispositions has considerable implications for selecting, preparing, and supporting peer mentors working with students in learning environments such as those taking place in makerspace classrooms. One implication is the need to simply bring to the awareness of the peer mentors the potential impact their dispositions can have on student development and success in the course. A second implication is the possible need to provide peer mentors with professional development opportunities to develop further and exercise their dispositions to refine and further understand how they can impact student learning and development in the spaces.

Our research also reinforced the critical role that technical expertise plays in helping students develop their engineering skills, as well as their engineering mindset and persistence through adversity. The implication of this finding is the potential need to provide additional opportunities for peer mentors to develop a deeper understanding of the tools, software, processes, and potential pitfalls associated with supporting student learning in makerspace classrooms. A second implication is the need for peer mentors to rely on each other as team members who can support each other as they encounter unfamiliar situations or need encouragement themselves as they attempt to support student learning in the spaces.

Limitations and Delimitations

Common to social science research, our study has limitations and delimitations. Our first limitation was the inability to engage specific groups of students in our research project. The students could choose to participate in our research project and complete our survey (as they should). Thus, there is the potential lack of representation by a diversity of students in our sample due to the inability to ensure that specific students participate in our study.

A second limitation is the inability to follow up with the students to understand their responses better. Since participation was anonymous, we could not associate any responses with specific students. Thus, we could not follow up with them after they completed the survey to gain clarity in understanding their responses.

A delimitation of our research is the nature of survey research, which constrains the depth of participant responses. While students were provided unlimited length for their free responses, they likely truncated their responses due to time constraints or lack of motivation to provide in-depth responses. We are considering using a combination of surveys and interviews to gather more in-depth responses.

A second delimitation was the inability to associate specific mentors with participant responses. Being able to follow up with the mentors with questions based on the student's responses would have allowed us to bring further clarity to mentor engagement in the spaces and their perspective of the student's learning. It is important to note that this is the first of many planned research projects associated with this funded project. Thus, we hope to resolve some of these issues in future studies.

Conclusion

Our initial research study focused on how peer mentors impact student learning in a first-year engineering design course in a makerspace classroom. We found the peer mentors influence multiple aspects of student learning and development. We also exposed multiple facets of the mentors' work that influenced the students' development, including their knowledge, interactions with the students, experience, and dispositions. Our future research will focus on how efforts to enhance the peer mentors' effectiveness further catalyze student learning and development as engineers.

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