2018 ASEE Annual Conference & Exposition
June 24–27, 2018
Salt Palace Convention Center
Salt Lake City, UT
Paper ID #23250

Equity in Collaboration: My Ideas Matter, Too! K-12 Students' Negotiation of Social Status in Collaborative Engineering Teams (Fundamental Research)

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Abstract

Within pre-college (K-12) engineering education, the curriculum design integrates students working with partners or teams on projects as standard practice in the curriculum design. However, with a need to increase participation in engineering and other STEM career pathways, introducing engineering in pre-college settings has become a central avenue for access to STEM career pathways for many students. Pre-college learning experiences are opportunities to develop students' interests further and continually transform their identities. This period of development highlights the importance of introducing pre-college engineering activities to students that are engaging for all students and consider the needs of students from underserved, underperforming, or underrepresented populations in STEM fields. In pre-college settings, positive collaborative experiences situated with engineering concepts could promote interests and continued engagement with pathways to engineering careers. However, ineffective collaborative experiences may exacerbate equity issues (e.g., underrepresentation) in engineering classrooms which may deter any future participation with the discipline.

The objective of this study is to understand how students', from low socioeconomic backgrounds, social positioning influences peer-to-peer relations and their status within an engineering team. Furthermore, we aim to explore how this position relates to their engagement with engineering concepts, practices, and habits. We expect the rich examples of how K-12 students experience status in collaborative engineering projects to inform curriculum design and instructional practice.

The methods applied follow a case study approach where video-recorded observations of peer interactions and one-on-one interviews comprise the data in this case. The case is a two-week summer engineering camp for students in grades 6-8. In this case study, we conducted interaction analysis of the video data by coding peer-to-peer exchanges and the associated impact on the students' engagement in the engineering task.

The results show that social status within collaborative teams manifests in three types of status-relevant interactions among students: taking authority, negotiating authority, or receiving direction from authority. The value placed on social positions taken up by team members resulted in both positive and negative impact on student engagement with the engineering concepts. The resulting impact shifted based on team dynamics throughout the project.

The findings from this work illustrate how status is manifested in engineering teams by precollege students with limited to no formal training in collaboration. These illustrations help

highlight how equity issues like underrepresentation of women or minorities can be further exacerbated by the pedagogical decisions of engineering educators. This exacerbation can directly influence the attitudes, perceptions, and interests of students in underrepresented groups which may prohibit their engagement in the future. The findings seek to provide examples of team dynamics for precollege engineering educators to help improve effective collaboration that promotes positive engineering experiences for students.

Introduction

In a field dominated by interdisciplinary and cross-functional teams to solve complex world problems, a common pedagogical practice in engineering education is to engage students with engineering concepts through team-based projects. This initial pedagogical practice began in higher education in an attempt to better align the curriculum and instruction with the practices of professional engineers [1] - [4]. Within higher education, collaborative learning first manifested as senior design capstone projects then expanded to include team-based design projects in first-year engineering courses and informal in-class collaborative activities. In each of these classroom interventions, students are expected to work together with a diverse group of their peers (e.g., cultural upbringings, race, gender, ability, and more) to solve a problem. Research suggest that students learning through collaborative engagement can result in positive influences on student achievement [3], [5], [6], [7], [8], [9], [10], [15], persistence [8], [9], [10], [11], [12], interpersonal skills [7], [10], [13], [14], [15], [16]. These positive influences and the industry demands have elevated collaborative learning to a core pedagogical practice for quality engineering education at all educational levels [2], [4], [17].

Within pre-college (K-12) engineering education, the curriculum design integrates students working with partners or teams on projects as standard practice in the curriculum design. In this context, effective integration provides similar student benefits as those demonstrated in higher education [18]. However, with a need to increase participation of students from underrepresented communities in engineering and other STEM career pathways there is an increased awareness on the quality of engineering instruction being introduced in pre-college settings. These pre-college learning experiences are opportunities to develop students' interests further and continually transform their identities [19], [20]. This period of development increases the importance of introductory pre-college engineering activities that are "inviting and engaging for all students, particularly those who are underserved, underperforming, or underrepresented in STEM fields, including girls, minorities, students from low socio-economic backgrounds, students with individualized education plans, and English-language learners" [21, p. 117]. In pre-college settings, positive collaborative experiences situated with engineering concepts could promote interests and continued engagement with pathways to engineering careers. On the other hand, ineffective collaborative experiences may exacerbate equity issues, like underrepresentation, in engineering classrooms by deterring students from future engagement with the discipline [6],

[19] - [24]. This disengagement is counterproductive to the goals and initiative so the engineering community focused on improving diversity within the field.

To date, research in collaborative learning within engineering education is primarily situated in higher education and often investigates implementation strategies, instruction, grouping strategies, or evaluations and assessment practices with a limited focus on equity issues within the engineering classrooms. However, when engineering education classrooms integrate collaborative pedagogical practices without an awareness of status differences the learning experience could reinforce stereotypes and inequity within the classroom [22] – [24]. Inequities in the engineering classroom due to accepted pedagogical practices are counterproductive to creating diverse and inclusive spaces. The research about such inequities within collaborative engineering teams is mostly situated in gender biases with limited evaluations of forms of status constructs within group dynamics (e.g., academic ability, race, ethnicity). Status is a socially constructed hierarchy of positions within the social network. These status positions identify some members of the team as high-status and others as lower status, which influences expectations and influence within the group. In addition, the status positions taken up by individuals within the team can influence their sense of belonging, self-confidence, and engagement with discipline concepts and practice. Understanding the influence of status is integral to the conversation regarding increasing participation, especially for the inclusion of underrepresented populations, in engineering through quality engineering opportunities that are inviting to everyone.

The questions guiding this study are (RQ1) how do peer-to-peer interactions during engineering design activities influence the social status of students within the team hierarchy? and (RQ2) how does the adopted social position within the team's hierarchy influence the students' engagement and the engagement of others during the engineering design project? To investigate the influence of social status within engineering team structures, we conducted a case study of students (grades 6-8) engaging in an engineering design project during an engineering summer camp. We expect the findings to help inform the development of team-based engineering activities and curriculum that creates equitable learning opportunities in engineering classrooms that engage all learners with engineering concepts and practices to promote participation in STEM career pathways.

Theoretical Framework

In this study, we employ Berger, Cohen, and Zelditch's expectation states theory to understand how students' social status manifest in engineering design and the influence of social status on team engagement [26]. Expectation states theory seeks to explain social status hierarchies within interpersonal relationships. This theory evaluates the influence individual status characteristics, and social interactions have on developing hierarchies within social structures. Expectation states theory suggests that people develop status expectations for themselves and others in a group predominantly based on their beliefs of the social value of others, which affect the interactions and authority in the group [26]. This theory is applicable in settings where groups are working toward a collective goal, and the task requires the group to consider others' perspectives [26] – [30]. This theory includes three components: (1) status characteristics, (2) social rewards, and (3) interchanges between people [26]. The first component associates abilities to the individuals based on their status characteristics as they are deemed relevant to the group goal [26] – [30]. Within the structure of education, this attribution of abilities to members of the group identify who are considered competent knowledge holders [26] – [30]

In this context, status is a person's position within their social network [26]. Within the structure of teams, status of individuals can be constructed based on the expectations of others about their value to contribute to the team's goals [26] - [30].Therefore, individuals with higher status within a group have a greater influence on the team's decisions than other members [26] – [30].Therefore, these status beliefs can impact self-confidence and engagement with the domain knowledge [22] – [24].

Methods

This study used a case study approach to investigate how social status within teams of middle school students influence their engagement with engineering design projects within the context of a summer camp that targets the participation of middle school students from low socioeconomic backgrounds [31], [32]. The case under investigation is a subset of the larger five-week summer camp that services over 400 campers from grades 3-8 each year. The campers self-reported demographics were as following: 35.0% Hispanic/Latinx, 35.7% White, 17.0% African American or Black, 5.4% bi/multiracial, 4.2% Asian, 0.4% American Indian or Native Alaskan, 0.2% Native Hawaiian or Other Pacific Islander, and 1.9% undisclosed. Due to the camp size, this case included in this study is a representative sample of the student teams. The student teams include students entering grades 6-8 who worked on an engineering design project for forty-five minutes a day over a two-week period. During this time, the research team collected video data of the teams engaging in the engineering design project to capture naturally occurring social interactions within the engineering design process [33]. At the conclusion of the camp, semi-structured team interviews were conducted to discuss their experiences with engineering design. At the conclusion of the camp, the research team transcribed the video data for analysis.

Participants

A total of eight teams made up of four to six middle school students entering grades 6-8 voluntarily participated in this study (n = 43). It is important to note that participant attendance was sporadic at times due to other summer commitments (e.g., family vacations) since this study takes place within the scope of a larger summer camp. Consistent attendance is a common challenge within informal educational programming. As a result, we chose to analyze the eight teams based on the following: teams that represented the status characteristics of the larger camp population; teams with consistent attendance for all team members; and overall team performance on project task. In addition, all of the participants identify as being members of families at or below the federal poverty guidelines. The group of participants consisted of 24 boys and 19 girls from diverse ethnic and racial backgrounds (e.g., White, American Indian or Alaska Native, African American, Latinx/Hispanic, and Multiracial).

Camp Context

During the engineering design session, student teams work in a community space setup to be a mobile makerspace. A makerspace is also known as a fabrication lab where ‘‘where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products’’ [34, p. 205]. The community space includes large tables to promote team collaboration while working on their design activities, a variety of found materials (e.g. cardboard, glue, paper, markers, etc.), electrical circuits (e.g. motors, buzzers, lights, etc.), 3-D printers, and computers that are accessible to all members of the team throughout their design project.

The research team grouped students into teams based on the interests each student reported at the beginning of the camp. With limited information about students' academic abilities, the camp instructors focused team formation based on the students' interests and on limiting disparities as they relate to status characteristics of gender, ethnicity, or race whenever possible. Each day, students entered and sat with their teams as the camp instructor introduced the engineering skill or practice and the day's goals. The teams then began working on solving a social problem (e.g., bullying, homelessness, and more) within the context of their self-reported interests. During the camp, the instructors introduced a design change request to all student teams and requested its incorporation into the final design. In addition, student teams explained their prototype to the larger camp community twice. The first time to receive feedback to be incorporated in their final design and at the conclusion of the camp.

Data Analysis

We used interaction analysis to identify status-relevant interactions among members of the team during the engineering design project [33]. In the first phase of data analysis, we reviewed the video data to determine what interactions within the project are status-relevant among team members engaging in engineering. Then during the second phase of data analysis, we reviewed the status-relevant segments to determine how students' status influence their engagement with engineering concepts.

Results

During data analysis, we identified three status-relevant interactions. We defined status-relevant interactions as social exchanges (e.g., words and gestures) between team members that manifest as team members taking authority positions, receiving directions from authority members, or negotiating authority within the engineering design process. Within the context of the engineering design process, the status-relevant interactions in most teams were constantly changing by positioning and repositioning members as high-status (e.g., taking authority), equal-status (e.g., negotiating authority), or low-status (e.g., taking direction from a higher status member). Once a team member's status was constructed within the teams' power hierarchy, the team response determined the level of engagement of the team's members (e.g., increase, maintain, or disengage) with the engineering project. These findings align with previous research on status differences within collaborative learning environments [6], [7], [35].

Below are segments of the transcribed video data to provide evidence of the manifestation of social status during social interactions in engineering design (RQ1) and the resulting influence on engagement (RQ2):

High-status

Within the team structures, high-status members obtained their position in two ways: self-assigned or team-assigned. High -status members who self-assigned their position in the team's hierarchy often took the initial actions to begin the engineering project. These individuals' actions included developing strategies to complete the project, organizing or distributing tasks, or taking individual actions without consulting other team members.

In this example, the team was discussing their ideas for incorporating the change request into their design with the Instructor (I). This team included three boys and one girl. In the exchanges with the team members, Student A treated all students the same regardless of their gender.

> I: How can you find the shopping cart?
> Student A (high-status member): Umm…
> Student B: I don't know.
> Student A: By smelling it.
> I: Smelling it.
> Student C: You could have one of those, uh. You could have one of those. Umm, like.
> Student B: Sticks that you can touch with.
> Student C: No, those things that like make noise.
> I: A noise maker, yeah. You could put that on the shopping cart so you could hear it. It could beep or something. It could say, "hear is the shopping cart".
> Student B: *(raises hand)* Or maybe, or maybe, or maybe. You could have one of those dogs that can walk you around.
> Student A: *(with head on table)* Yeah, that's a guide dog.

Student B: That has like a red thing.
I: Oh ok, well that is not something you can change to the shopping cart. But write down the noise maker idea. *(Instructor leaves group)*
Student B: I'm not going to make any of your guys' ideas.
Student A: Well, two of them didn't make sense. And the other one, we aren't doing.

After this interaction, the Instructor revisits the team.
I: What are you making?
Student A (high-status member): We are making ropes, so blind people can get the stuff without asking for help.
I: So, ropes. Explain to me how that would work?
Student A: So, like. So, they are connected to the walls. So, a blind person can grab onto the ropes and move around and stuff.
I: Alright, how did you guys come up with that idea?
Student B: He talked about it!
I: He talked about it?
Student B: Yep.

In every opportunity for the team to explain their idea to an instructor or the larger community, Student A was the only person providing an explanation. The other members of the team did not elaborate on the ideas presented by Student A. At times during the project, Student A assigned task to the other team members to be completed. Student A did not consult with any of these members for approval of design decisions. In addition, the noise maker location device proposed by Student C did not make it into the final design. Since, Student A completed the bulk of the work on the project, other members of the team often became easily distracted from the project.

On the other hand, some high-status members obtained their position through team appointment. These individuals were verbally identified by their team members as "smart" or their interactions with other team members resulted in consultations or approvals. It is important to note that within these teams, the social status of team member did not change over the two-week period.

In this example, the team was discussing ways to improve their prototype to meet the requirements of the design change request. This team included two girls and three boys. In this exchange, two team members are discussing options for a potential change when Student D is identified as a high-status member based on his perceived competence by Student E. From this point forward, members of the team consulted Student D for approvals to design decisions.

Student D (high-status member): We should take out all of the tables and furniture so that they can't bump into them.
Student E: I agree because you're smart.

Student D: I'm just kind. I was just joking.
Student E: Yeah, I guess, we do need the furniture though.
Student D: Yes, I was just kidding.
Student E: Well, we should make the furniture safe, then.
Student D: How so?
Student E: I don't know.

Despite gaining an authority position, Student D often used facilitation strategies by questioning other team members in a similar fashion as "How so?" in this excerpt to consult and maintain engagement other team members in their engineering design project. The continual engagement of other team members was demonstrated during team presentations when Student D was absent. The other team members were able to explain their prototype to the larger community demonstrated shared knowledge of the project. However, if Student D had not continue probing the other members of the team to engage in the project or if they did not respect Student D as a leader, members of this team would have missed out on a learning opportunity.

Equal-status

Other teams within the case co-constructed knowledge as a method for maintaining equal-status. In equal-status teams, the social positions of authority could be obtained by any member of the team at any time. To maintain equal-status, members used explanations, elaborations, and negotiations to understand others' perspectives, make compromises, and incorporate approved design elements.

In this example, the team was working on creating their initial prototype for improving safety of visitors at their community center. This team included four girls and one boy. This team demonstrated the equal-status members by explaining their idea to their team members and the team either accepted, elaborated, or negotiated before the idea was implemented. In this excerpt, the team is talking with the Instructor (I) about the ideas they are in the process of building. Student F begins the conversation, but throughout the excerpt Student G and Student H provided additional elaborations. These elaborations demonstrate active listening skills and the ability of the students to identify gaps in their shared knowledge structures. In addition, when Student H is asked by the instructor to elaborate on how they could create the GPS idea, Student H reserves answering before talking to the team by stating "We haven't talked about. Talked about that yet."

Instructor (I): So, what ideas do you have?
Student F: We were thinking about like, um, uh, we have like adopt like dogs that sort of blind people.
I: So, like safety. What is your room about?
Student G: It's like safety outside.

I: Safety, oh yea safety. So, dogs to help them outside. What is something you could make or that you could invent that doesn't exist yet?
Student H: I said make a GPS like object that helps them navigate the people. Like tell them to stop if there is a car coming or something. Or go right.
I: Oh ok, so they carry it with them or have it with them. Oh. I like that.
Student H: Rent sticks too.
I: Ok, I like those ideas. I like the idea of GPS. What kind of objects do you think would be good someone?
Student H: We haven't talked about. Talked about that yet.
I: Ok, so. What else do you have to think about when you think about solving a problem for someone who is blind.
Student F: We have to remember they are probably trying. They can't see so they can't visibly find things. Or do. Probably like if , the GPS will probably have to be voice commands.
I: Right they are not going to see so it has to have voice commands.
Student F: The thing is they are probably more reliable on their hearing so we can use that to our advantage.

The authority in this team frequently shifted to whoever had the floor in that moment. In some cases, team members didn't understand or had a different understanding of the problem, which lead to negotiations before a decision was made. As a result, in the team interview, members of this team talked about combining ideas to make their final prototype and commented on enjoying working with their team members. As a result, all of the members of this team reported a positive attitude toward engineering. Ideally, equal-status in teams is where we would like all teams to operate when engaging in collaborative engineering design project.

Low-status

In a couple of the groups, members were positioned as low-status if they did not participate in the activity and the other team members did not try to engage them with the material. In most teams low-status members were ignored throughout the project. If the low-status member completed work it was done as an individual and never was incorporated into the main design unless it was a task given by a higher-status team member. As a result, the low-status member did not have access to equitable learning opportunities within the engineering context. In some cases, low-status members mentioned "dislike" or "hating" engineering.

In this example, the team was discussing their ideas for a prototype to clean pollutants out of water. In this exchange, the team is trying to decide and plan a solution that they want to build as their prototype. Student J and Student K are defining their problem state and beginning to brainstorm potential solutions. In the middle of the discussion, Student J asks Student L, who has not been involved to this point, a question to prompt Student L engagement with the tasks.

J: So, what is your idea for that one? *(Talking to Student L)*
K: I'm trying to think. Would it better if we had something that put all of them together.
L: *(bangs on table with one fist).* Ugh, I can't stay awake. *(Teammates ignore his behavior. Bangs again with both fist).* Ugh, I can't stay awake.
K*: (continues talking, ignoring Student L)* Said like animals, people, plants, and all living things.
J: What's your idea? *(Again, talking to Student L. No response from Student L)*
K: *(raises voice and puts hand on hip when talking to Student L)* Do you need some coffee?
J: I don't like coffee.
K: Ugh, alright *(shrugs).* My ideas is basically this box is the height.
J: The box.
K: Yeah, it could be like this way. *(turns box vertical to the table to show Student J)* See the water flows down and all the trash and stuff goes with it. So, then it is like this and only the water would go and the trash could go through here and all the trash would be out and the water out. The box would be the idea. I don't know.
J: So, we could have, like, I don't know. Like a tube and then like a container here and a container here that goes all the way through here. Then a tube out and out. The trash goes in here, the bad water goes in here, and the good water goes out.
K: Say that again. *(Student J slightly throws head back, looking up at ceiling).* I'm kinda getting it.
J: Ok, did you know that water is pee, but they get the chemicals out.
K: YES!
J: Yes, so that is what it is. The chemicals…like…to get…
K: *(interrupts)* to have an area where it cleans the water.
J: *(nods)* Yeah, it cleans the water and gets the trash out.

At this time Student L has still not participated in the conversation, but Student J continues to ask for Student L questions. Student J is trying to create an environment of equal-status with Student L, but Student L is unwilling to participate. The team continues discussing their plans.

K: So…I'm thinking.. maybe, yeah, if we will a where the wall goes to have a small flat thing like J: tube that goes into a box that has a strainer and goes into the other one and that is where it extracts the container.
Instructor: How about you draw that here so we don't forget tomorrow when we are 3-D printing.
J: Are you ok with that idea? *(Leaning into the table and asking Student L)*
L: Yes.

At the conclusion of the first two days, Student L still has not participated despite Student J's actions to get Student L involved in the project. On the third day of the project, Student L finally becomes engaged in the project while working alone with Student J. It appears that Student J's consistent probing of Student L for approval of the team's decisions allowed for Student L to get involved. Throughout the remainder of camp, Student L participated in the project by receiving directions from Student K and J. Despite often receiving directions from authority, Student L was able to present the team's ideas to the larger group demonstrating shared knowledge construction. Despite this positive progression, at the conclusion of camp, Student L voices "dislike" towards engineering as the team is finalizing their prototype.

> L: *(Sitting off camera)* See, this is why I don' t like engineering.
> J: What?
> L: This is why. This is why I don't like engineering.
> J: Uh. I can't hear you.
> L: This is why I don't like engineering.
> K: What?
> L: This is why he doesn't like engineering.

As a result of Student L's experience with engineering, it is probable that Student L will not engage further with engineering in the future.

Implications

Ideally, we would have students engaging as equal-status members within an engineering team, which would build a diverse and inclusive engineering discipline. Equal-status would would mean that the team members view each other as equals with varying skills and abilities and could come to agreement on the various roles they might each play. It is important to recognize that teams will not always manifest in this way leaving opportunities for educators to be mindful in working toward equal-status in engineering teams. We have highlighted with a few brief examples what high-status vs. equal-status vs. low-status can look like in a team. We believe it is important to be explicit about good teaming behaviors and call out what it can look like when teammates are not treating each other equally or fairly. For example, in the example we presented of a high-status member, the actions of Student A could be interpreted as the student being decisive and a leader, behaviors we certainly like to see in students; however, if the student is not aware of the fact that they are making unilateral decisions, they could begin to alienate other team members. We recommend acknowledging the student for their great work, and also suggesting how they can integrate their team members' voices into the work as well. Likewise, the example of the low-status team member was not willing to participate despite the other members of the group trying to involve this member. The low-status member may still have some learning gains, but will most likely leave with a negative impression of the discipline.

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