Lessons Learned: Implementing Equitable Teaming Practices in First-year GE Courses

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Background and Motivation

Aspiring engineering students at Virginia Tech initially enroll in a General Engineering program during their first year of the curriculum. In this program, students are expected to develop, along with other skills, professional teamwork strategies in an engineering setting through a semester-long team project. These types of team projects have been shown to influence students' sense of belonging as they begin their studies, something that can be a factor in retention and success in an engineering program. Many instructors have observed that incoming first-year students often struggle with teamwork, and several instructors from the program attended a workshop in Summer 2022 led by Worcester Polytechnic Institute (WPI) with lengthy experience leading project-based learning first-year engineering courses. The facilitators of this workshop provided activities that can be integrated into existing or new courses to help foster equitable teaming practices in a project based learning setting. These tools had previously been implemented in a program at WPI and are available in Pfeifer and Stoddard, 2020 [1]; this paper explores implementations and impact of integrating these equitable teaming tools at a larger scale.

The instructors of the first-year engineering course who participated in the aforementioned summer program are granted a degree of autonomy in how they approach teamwork in their courses and chose to implement the equitable teaming tools from the Summer 2022 workshop to various degrees in their classes in the Fall 2022 semester. The full list of available teaming tools included: 1) pre-readings related to the importance of diversity on teams, 2) individual asset maps encouraging students to explore how their own backgrounds could be valuable and applied in the course, 3) team asset charts designed to facilitate a breakdown of work for team assignments in a way that draws upon the diverse backgrounds of all team members, and 4) team processing documents guiding students through reflective questions regarding their team's strengths and areas to grow. Tables 1 and 2 elaborate on the extent and practices used by each of the study instructors, also authors on this paper, with respect to implementation of these tools.

Description of Equitable Teaming Tools

For the asset mapping activity, students were given an example of a pre-filled individual asset map and a template to construct their own asset map. The asset map asked students to document their personal assets related to areas such as experiences, interests, technical expertise, teamwork skills, personal background, and extracurricular activities that might be useful in the context of the first-year engineering course they were enrolled in. They were also asked to identify three areas that they wanted to grow in.

The pre-readings assignment asks students to read and reflect on considerations of different types of diversity and the value of diversity in teams. The three assigned readings included: "How Diversity Improves Collaborative Problem Solving," [2]; "Point of View Affects How Science is

Done," [3]; and "When I Learned the Value of Diversity for Innovation," [4]. Students were asked to respond to three reflection questions regarding the benefits and challenges of diverse teaming, the types of cognitive and identify diversities, interesting aspects in the readings, and their personal goals for teaming.

The Team Asset Chart assignment tasks student teams with reviewing their individual asset maps and each team member's areas for growth from the asset mapping activity to plan for equitable teamwork in an upcoming team project. The team then identifies specific tasks that are needed to complete an upcoming team project assignment, and then to assign two people to each task. One person assigned to each task should have assets related to that task, and the other person should have an interest in growth in that area. The asset chart effectively helps student teams to both take advantage of assets each individual team member brings to their work and allow students to learn and grow.

The Team Processing Document assignment gives student teams an opportunity for guided reflection and discussion on various characteristics of equitable and effective teaming and prompts student teams to develop an action plan for their future team work. The guided discussion questions include prompts related to team communication, team leadership, team decisions and equity, team commitment, team productivity, use of team assets, and other team problems (such as time on social media and/or games, late work, etc.).

Integration of Equitable Teaming Tools

As noted previously, instructors could choose the extent to which the tools would be integrated in their classes in Fall 2022. Two instructors (A and B) chose to implement all four tools, two instructors (C and D) implemented some, but not all the tools, and a fifth instructor who led two course sections did not implement the tools this semester. However, this instructor did participate in quantitative data collection related to students' perceptions of teamwork. Notes regarding adoption of teaming tools by each instructor are given in Tables 1 and 2.

Table 1: Full Integration - all teaming tools were used

Instructor (# of sections)	***Pre-readings***	***Individual Asset Map***	***Team Asset Chart***	***Team Processing Documents***
A (5)	Assigned readings and reflections at the beginning of the term	Assigned individual asset map at the beginning of the term; students used to introduce themselves to new team members; included an individual reflection question on how asset maps could be used for equitable teaming	Assigned to team for first of three team project assignments for the term	Assigned to team after the first and second of three team project assignments for the term
B (2)	Assigned readings at the beginning of the term with an associate discussion board and in-class discussion.	Assigned individual asset maps at the beginning of the term and encouraged students to refer back to it when dividing tasks throughout the semester.	Assigned to teams three times throughout the semester to encourage division of work for major project milestones and deliverables	Assigned to teams twice throughout the semester after major deliverables

Table 2: Partial Integration - one or more teaming tools were used

Instructor (# of sections)	***Pre-readings***	***Individual Asset Map***	***Team Asset Maps***	***Team Processing Documents***
C (2)	Assigned readings at the beginning of the term with an associate discussion board	Assigned individual asset maps at the beginning of the term and encouraged students to refer back to it when dividing tasks throughout the semester.	Not used	Assigned to teams once after the second major team deliverable of the semester
D (4)	Not assigned	Assigned individual asset map at the beginning of the term; students used asset maps to introduce themselves to new teammates	Not used	Not assigned

Study Intent and Supporting Literature

The aim of this study is to measure the impact on students' experience of teamwork after a semester implementing the equitable teaming tools. Data collected included student reflections on their teamwork experience at the end of the semester and their sense of psychological safety in their teams as measured by a survey. Psychological safety has been shown to be an important indicator of the effectiveness of teams in engineering and other disciplines [5], [6]. Equitable teaming tools are intended to reduce stereotyping and task-assignment bias with the expected result of improving team dynamics and productivity [7]. Therefore, the research question that guided this study is as follows: *How did the implementation of equitable teaming tools impact students' perception of psychological safety while working in teams in a first-year engineering course?*

Psychological safety has been described as a willingness to share thoughts and ideas without fear of reprisal [8]. Students who feel that they can share ideas and questions with fellow team members feel "safe" enough to do so and are not afraid of making mistakes. This is especially important in a team, especially when a team leader cannot be expected to know what everyone is thinking, or predict what questions should be addressed [8].

To help define psychological safety, seven attributes exhibited by successful teams were identified by Edmondson [6] (a more detailed description of these attributes can be found in the Methods section of this paper), namely:

- Communication: members provide and receive information objectively
- Coordination: balancing workloads among members in order to work effectively
- Cooperation: working together and helping one another
- Composition: members reflect on/respond to their team's strengths and weaknesses
- Conflict: conflict is addressed and mitigated constructively
- Creativity: members share ideas and generate more ideas together
- Cohesiveness: group pride in working toward a common goal

CATME peer evaluation surveys have also been used in the past to measure students' perceptions of teamwork, including their views of psychological safety [9]. More information on how CATME collects these views is listed in the Methods section of this paper. The questions also reflect the role of trust among team members, where psychological safety appears to be a manifestation of trust [9].

The presence of psychological safety in teams can also be an indicator of team resilience, which enables team members to exert greater flexibility and persistence, inspired by a motivation to do what is necessary for the team to be successful [10]. Resilience becomes important when a team faces the uncertainty brought about by changing conditions and circumstances, such as the conditions surrounding the Covid-19 pandemic or similar upheavals in the normal course of events.

Methods

The design of this study resembles an explanatory mixed-methods approach, where qualitative data is used to explain or illuminate the findings initially gathered via quantitative methods. However, the collection instruments were developed independently and applied almost at the same time during the semester. Specifically, we asked students to complete an existing Likert-scale survey on psychological safety using CATME and also to respond to three open-ended questions about their teamwork experience developed by the authors. The details are presented in the following subsections.

Data Collection

Data was collected from 15 sections of a first-year engineering course denominated *Foundations of Engineering* at Virginia Tech, with each section having approximately 65 students. The equitable teaming tools (ETT) were fully integrated in seven sections, partially integrated in six sections, and not integrated in two sections of the course. Table 1 and Table 2 above provide details on what fully and partial integration entailed. As a part of their class activities, students across all 15 sections used CATME to complete multiple peer evaluations at different times of the semester [11]. The peer evaluation questionnaire included the block related to psychological safety, which comprises the following items:

I1. If you make a mistake on this team, it is often held against you. [scale reversed]
I2. Members of this team are able to bring up problems and tough issues.
I3. People on this team sometimes reject others for being different. [scale reversed]
I4. It is safe to take a risk on this team.
I5. It is difficult to ask other members of this team for help. [scale reversed]
I6. No one on this team would deliberately act in a way that undermines my efforts.
I7. Working with members of this team, my unique skills and talents are valued and utilized.

Student responses to these items were recorded on a 7-point accuracy Likert-type scale ranging from *Very Inaccurate* to *Very Accurate*, with a neutral middle point (*Uncertain*). Data for this study included students' responses to the final round of peer evaluations only, conducted within the last two weeks of the semester.

In addition, students in the 13 sections where equitable teaming assignments were partially or fully implemented responded to a course exit survey including three open ended questions on teamwork that read as follows:

Q1. What are some specific practices or behaviors that you think contribute to an engineering team performing well?
Q2. How well do you feel your team has embodied these practices or behaviors this semester?
Q3. What is something that you've learned about working in teams this semester that you may be able to use to work more effectively in future teams?

These questions were formulated as broadly as possible so that they would not lead students to discuss aspects related to equitable teaming and psychological safety only. On the contrary, the aim was to explore whether students would spontaneously bring up such aspects as a result of class activities and assignments rather than explicit question prompts.

Data Analysis

For the quantitative portion of the study, we focused on student responses to the block of seven Likert-type CATME items regarding psychological safety. Data was anonymized and consolidated, keeping only identifiers for the sections taught by different instructors. As mentioned before, sections taught by different instructors were split among three different levels of implementation of ETT: full, partial, and none. Inferential statistics helped us then explore the dataset for significant differences across these groups in students' perceptions of psychological safety in their teams.

During the qualitative portion of the study, deductive coding was used to better understand and explain the results obtained in the quantitative portion [12]. A codebook derived from the literature supporting CATME's survey design was used to guide the coding process (see Table 3) [5]. A random subset of ~20% of the responses from each section was extracted and then consolidated into a new dataset, randomized, and evenly split across the authors for coding so that each author would randomly code a similar number of responses from students in any section. More than one code could be assigned to a student entry, without repetition. Codes thus obtained were used to gauge their prevalence. An additional code was assigned to answers to question Q2: *How well do you feel your team has embodied these practices or behaviors this semester?* Four possible codes were used here: *Fully embodied*, *Partially embodied*, *Not embodied*, and *No evidence*.

Table 3. **Codebook (adapted from Cole et al. [5])**

Code	Explanation
Communication	Being respectful of others' ideas, listening, and general communication where members provided and received information which led to the attitudinal, behavioral, and cognitional change of a team, teams indicated whether they were able to communicate well throughout the process.
Coordination	Coordination discussion includes accomplishing tasks in an efficient and timely manner, work contribution and participation by team members, absence and punctuality of team members that are linked to the formation or decline of psychological safety.
Cooperation	Collaborating well, working together, and helping each other could impact the formation of psychological safety.
Composition	Participants commenting on the characteristics of their team members and the individual factors that are related to the outcome of the team performance including openness and extraversion.
Conflict	Conflict occurred when team members possessed different views that might have led to a negative impact on psychological safety.
Creativity	Idea generation among team members that inspires more creativity during the process.
Cohesiveness	Interpersonal attraction, commitment to task, and/or group pride when team members worked toward a common goal. Having good or poor connections with team members when discussing positive and negative interactions.

Results and Discussion

Quantitative Outcomes

The CATME Psychological Safety scores from the student responses were compared based on the degree of implementation of the equitable teaming tools (ETT). As mentioned previously, there were three levels of implementation of ETT across sections: *Full, Partial, and None.* We conducted an ANOVA test to compare significant differences across all three groups. In addition, we also conducted independent t-tests to compare the significant difference between each level. Table 4 shows the outcome of the statistical tests. From the ANOVA test, it is seen that there is significant difference across the three levels of intervention. The mean score for partial intervention was highest among the three levels, however there was no significant difference between the mean scores from Full and Partial intervention. From the t-tests it was found that there is significant difference between the mean scores of Full implementation and None and between the mean scores of Partial implementation and None.

Table 4: Quantitative Results by ETT Implementation Level

Equitable teaming tools implemented	***N***	***Mean***	***Var***	***Full-Partial (p-value)***	***Full-None (p-value)***	***Partial-None (p-value)***	***ANOVA (p-value)***
Full ETT	402	5.995	0.548	0.3520	**0.00025****	**9.98E-05****	**2.75E-05****
Partial ETT	395	6.015	0.470				
None	121	5.672	0.839				
significance levels indicator: p-value **(p <0.05)*, (p<0.01)****							

Note: Significant p-values shown in **bold**

Beyond the differences found, it is worth noting that the mean scores for all levels of implementation are well above 4.7, which is a subjective minimum threshold used to identify teams potentially struggling due to issues related to psychological safety [11].

Qualitative Outcomes

Teaming Practices and Behaviors That Contribute to Effective Teamwork

The analysis using deductive coding from the codebook (Table 3) allowed us to classify and identify different practices or behaviors that the students related to the outcomes of teamwork. The top four behaviors or practices that students thought contributed to effective team performance were *Communication, Coordination, Cohesiveness* and *Cooperation.* Figure 1 is a word cloud depicting the relative frequency of student responses with respect to each of the 7 Cs.

Figure 1: Relative prevalence of 7 Cs in students' responses

Communication was the most frequent factor cited by students and showed a dual approach. On the one hand, students discussed the possibility of freely expressing themselves and sharing ideas, a concept closely related to the main tenet of psychological safety. For instance, one student shared the following:

> *The first thing is comfortability. It is best advised when you meet up with your group for the first time [ ] to do some sort of ice breakers. Just getting people to talk with one another will do absolute wonders for the team. If everybody is comfortable with each other [ ] performance wise for the team will be good.* (Instructor C's student)

On the other hand, students would also highlight instances where open communication was necessary to share information about what team members should be doing, what help is needed, what parts of an assignment are still pending, and other logistic aspects of teamwork. The next couple of excerpts illustrate these points:

> *I think that some practices or behaviors that I contribute to an engineering team the most are seeking help when it's needed instead of grinding my wheels too long.* (Instructor A's student)

> *I think the most important practices and behaviors that contribute to an engineering team are good communication skills and being able to evenly split up work and be reliable for the work you are assigned.* (Instructor B's student)

The previous quote is a good segue for the next top behavior: *Coordination*. There is a significant overlap between communication and coordination, where students place high value in communicating information that serves to split and complete tasks efficiently and timely. The next excerpt reinforces that idea:

> *To begin with, setting a plan is a must for every group. It allows for everyone to know what is expected and what needs to be done, so that there is no confusion among the group. Doing your part in a group even if it's something little helps make progress. It is important to do so because someone who doesn't contribute and just sits back ultimately holds the entire team back. This is where being able to hold each-other accountable comes into play. When someone is not playing their role, it is important to [] confront them (not in a rude way) and help them get back on track. None of this would be possible of course without having good communication skills. A team that is able to speak up and express themselves makes for a good team.* (Instructor A's student)

It becomes evident that coordination and communication have a significant overlap when it comes to the approach of smooth interaction between team members to guarantee that everybody knows what they should be doing and follow up with one another. The next top behavior,

Cohesiveness, was also discussed by students from a few recurring perspectives. One of them is the idea of commitment to task, often discussed as motivation:

> *The team being motivated and dedicated is also important because if some people aren't putting as much effort into the project as the others, it can cause tension and frustration between team members, as well as affecting the overall quality of the project*. (Instructor D's student)

Other recurring topics related to cohesiveness were opportunities for bonding and respectful interactions as a basis for establishing good connections among team members. Both can be illustrated by the following excerpt:

> *I believe that spending time outside of class together either working on the assignment or just hanging out can improve the overall group's mentality. Building respect is another part of being a good teammate. You cannot act like you are better than everyone else or your teammates will not like you and may not help you. Respect goes both ways and it is important when you are working for an extended period of time together as a group*. (Instructor C's student)

Finally, *Collaboration* was mentioned directly by many students. The next excerpt is a good example of a student discussing multiple Cs, including collaboration, in one statement:

> *Communication is a big part of an engineering team performing well as this is the best way for the projects to reach their maximum quality. A team project should be everyone actively working together and communicating different ideas. This communication could offer ideas that would make the project better. Another good practice is also collaboration. Having everyone on the same page and putting equal effort into the project makes it more cohesive and put together. And if every member of the team is motivated to put work into the project, it is less likely other members will fall behind.* (Instructor B's student)

As these excerpts suggest, communication is at the core of students' perception of what practices or behaviors contribute to effective team performance. Not surprisingly, communication overlaps to a great extent with the other factors summarized by the 7 Cs. Moreover, those other factors also present overlapping areas. Drawing from the word cloud (Figure 1) and the qualitative analysis of students' responses, Figure 2 presents a visual approach to the overlap described above. While we did find Composition, Creativity, and Conflict in students responses, Figure 2 highlights only the four Cs most recurring among students responses and with evident overlap supported by the qualitative results.

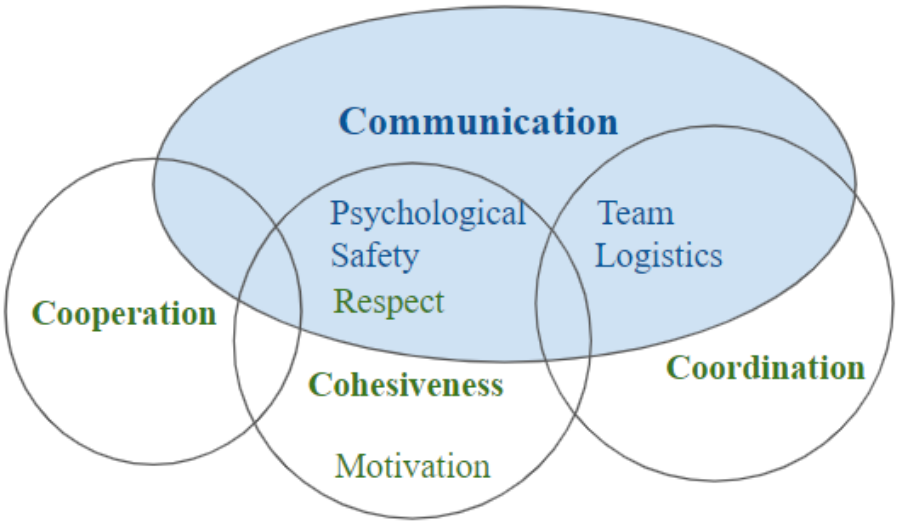

Figure 2: Overlap between the most prevalent Cs in students' responses

Perceptions of Embodiment of Good Teaming Practices

As illustrated by the previous excerpts, students would usually elaborate on two or three aspects when describing the characteristics of effective teams in their responses, and less often on four or more. Their assessment of the level to which their teams embodied good practices was therefore bound by the limited number of aspects they had in mind when answering. The coders did not focus on the number of good practices elicited by the response but instead on the overall assessment of the quality of the teamwork experience. For instance, the following quote exemplifies what was considered full embodiment of good teamwork practices and behaviors:

> *I think our team has been highly successful due to our use of all of these qualities. We communicate well the majority of the time, and any minor conflicts have been quickly shut down due to communication. Respect was upheld the entire time, each member saw each other as hard workers and we all cared about respecting the assignment as well. Finally, we all worked hard and contributed to the final projects we were working on to create a solid product for all assignments.*
> (Instructor A's student)

The previous quote comes from one of those few responses where communication, coordination, cooperation, and composition were highlighted. To contrast this idea of full embodiment, the following quote presents an example of what the coders considered partial embodiment of good practices and behaviors:

> *I feel that while our team has mostly embodied these practices, we could have done better. In terms of psychological safety, in my opinion everyone feels generally safe voicing a concern, even if it may be controversial. We have also had regular meeting times on a weekly basis. While I think this is a good starting*

> *point, I think it would have been more effective for us to have met two times a week, one of those times possibly being the weekend.* (Instructor B's student)

In the previous quote, the student presented an overall positive perception of psychological safety, but explicitly discusses room for improvement. This is an example of the caveats that resulted in the assessment of "partially embodied". Finally, the following excerpt provides an example of a student expressing how their team failed to embody good practices:

> *Simply put, we really haven't. Usually, we would have 3-4 people in class in the second and third modules of the semester. The same person would pretend to be sick for a month and a half straight, and usually two or so people would also skip class and leave the work to everyone else. Once again, I know not EVERYONE is like that and it's likely I just landed a team I can't relate to at all or even be able to work with entirely. I could absolutely work with one person on the team well because we were able to balance and build on each other's ideas, but beyond that, our teamwork was very limited.* (Instructor D's student).

Counting these codes showed that more than 57% of the students felt that their team seemed to have fully embodied the good practices or behaviors discussed when they described contributing to an effective team. 37% of the students felt that they have partially embodied the good practices and behaviors with some caveats. 5% of students responded that their team was not able to embody the good practices and behaviors discussed. Figure 3 shows the distribution of student responses in terms of their assessment of their team's level of embodiment.

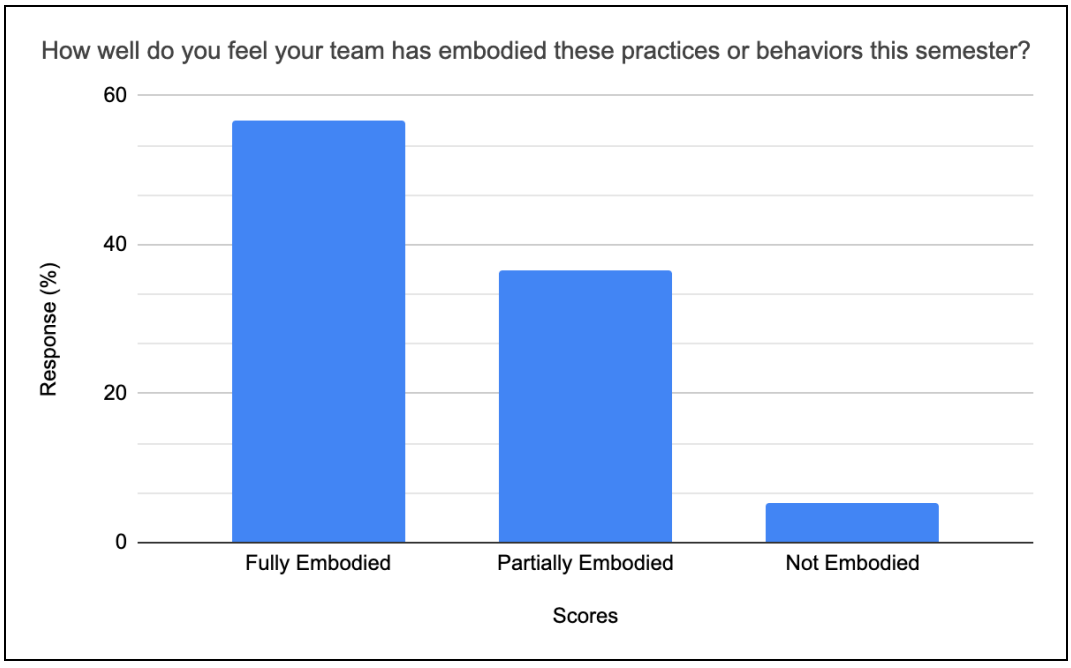

Figure 3: Student views of psychological safety

From the qualitative analysis, we also compared students' perception of embodiment of good teaming practices across two levels of ETT implementation. It should be noted that students in the sections where ETT were not implemented were not required to respond to the three open-ended questions. Hence, we only compared between Full and Partial implementation levels. From Figure 4, 59% of students in sections where ETT were fully implemented felt that their teams fully embodied the good practices or behaviors they described as contributing to an effective team, in comparison to 55% of students in sections where ETT were fully implemented. Also, 39% of the students in the Full ETT sections felt that their teams had partially embodied the good practices and behaviors in comparison to 35% in the Partial ETT sections.

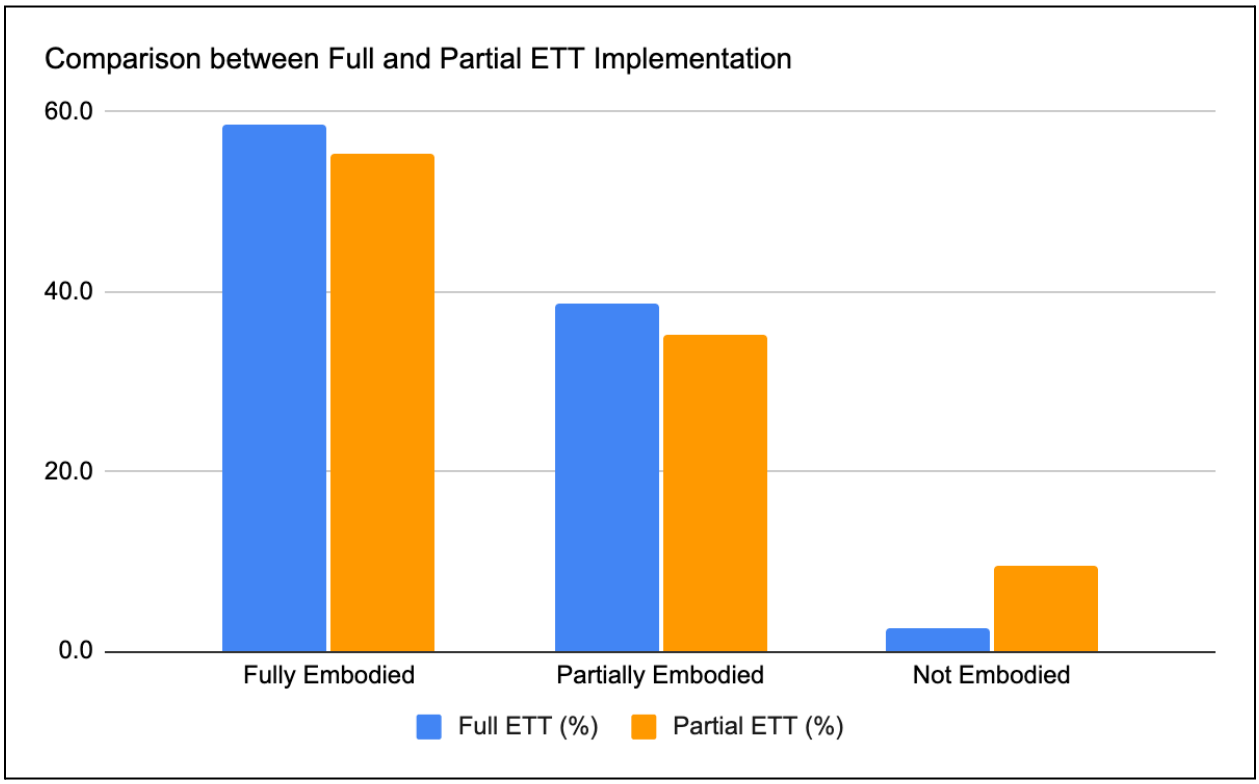

Figure 4: Comparison of ETT implementation

Conclusions

The results of this study suggest that integration of the aforementioned equitable teaming tools into the curriculum for a large first-year engineering program course can have a positive influence on students' views of psychological safety when working with their teams. Furthermore, even partial implementation of the tools appears to have a significantly positive effect on student's views of teamwork. This is especially important, as full implementation of the tools can occupy a significant amount of class time throughout the semester. It is worth noting that all instructors in this study used CATME to help form teams and promote peer evaluation multiple times over the semester. Specifically, CATME allows using students' self-reported demographics and skills to maximize diversity when forming teams, within constraints of

compatibility of schedules and composition of the whole class. Diverse teammates and frequent opportunities to provide feedback to each other could explain why psychological safety scores were good also among students in the sections where ETT were not implemented. However, the significant differences found suggest that the implementation of ETT effectively complements the benefits of using CATME.

The qualitative analysis of student responses to questions about teamwork indicated that, when equitable teaming tools are included, students can frequently identify important elements of teamwork such as communication, coordination, cooperation, and cohesiveness, among others. The authors of this study believe that the equitable teaming tools are an effective strategy to facilitate meaningful conversations about the importance of teamwork in engineering.

It should be noted that the study has several limitations, notably that these results are specific to the context in which the data was collected, and future work is required to determine whether the results can be generalized. Specifically, additional factors such as differences in instructors' approaches to other portions of the class, different projects, student demographics, or whether students are first year or transfer students could potentially affect the results. Additionally, the qualitative questions were not used in the group without ETT implementation, thus the results of the qualitative work only apply to situations in which at least a partial implementation was present. Further work would also be beneficial to identify the effects of different combinations of partial ETT implementation.

In conclusion, both the quantitative and the qualitative results (particularly Figure 4) support the finding that even partial implementation of ETT can result in an improved teamwork experience for the students in the context of this study, both in terms of their perception of psychological safety and their perception of how well their team embodied good teamwork practices.

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