Effect of psychological safety on the interaction of students in teams

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Effect of Psychological Safety on the Interaction of Students in Teams

Behzad Beigpourian, Matthew W. Ohland, Daniel M. Ferguson

Abstract

CONTEXT
Diverse contributions from team members have the potential to improve innovation in engineering student teams, but students must feel psychologically safe to contribute fully. Low psychological safety can decrease cohesion in teams and increase conflict.

PURPOSE
This study aims to explore trends in the psychological safety of students, teams, course sections and their effect on the interactions of students within the teams.

METHODS
We used multilevel (hierarchical) modeling to address our research question. The quality of teammate interaction is the outcome variable and is predicted by individual psychological safety in the first level, the team's average psychological safety in the second level, and the course sections' average psychological safety of students in the third level.

RESULTS
Based on the result, peer evaluations of the interaction each student has with team members (the outcome) can significantly be predicted by the psychological safety of a student and the level of psychological safety in teams. The sections' average psychological safety did not affect our outcome.

CONCLUSIONS
If we expect students to interact more with peers within the teams, we should make sure that psychological safety is high in both individual and team levels. It is possible that the lack of variability by the course section is a result of studying all the sections of a coordinated course.

KEYWORDS
Teamwork, psychological safety, multilevel (hierarchical) modeling, interaction with teammates

Introduction

Engineering graduates should be able to work in multidisciplinary teams [1], and for this purpose, teaching students to work effectively in a team is necessary, especially in the first year of study, in which teaching teaming skills is much easier [2]. For teaching teamwork skills, there should be enough knowledge about any factors related to team members as individuals and a team as a whole. One important factor is psychological safety (explained in more detail later in this paper), which increases team effectiveness by making team members confident that their team is a safe place for taking risk and participation. However, team effectiveness has not investigated in the engineering context as much as it has been studied in other fields using teams. In this paper, authors decided to explore trends in the psychological safety of students, teams, course sections and their effect on the quality of interaction each student has with team members.

Teamwork in Engineering Education Literature

Engineering instructors and researchers consistently are looking for ways to make the teaming process effective. There are several models for effective teamwork, including different factors, influencing teaming quality. Regardless of models' details, each factor has been of interest to researchers. Similarly, many engineering educational researchers have conducted research about these factors from team formation to team assessments [3]–[7]. In this section, we summarize these studies.

Teaming pedagogy might start with team formation. Students would like to work on smaller teams rather than the larger teams to be able to manage their teams [8]. Engineering education researchers have studied many team formation approaches, from student self-selection to instructor team selection. Any team formation strategy has its advantages and disadvantages [9], [10]. Although some researcher suggests avoiding self-selection, [9], some recommend to let students form their team because it will give them a sense of ownership and will increase their attitudes [9], [12]. Nevertheless, even these studies warned about some problems in the self-selection process, such as language and culture. Layton et al. [8] produced a team-formation tool to form teams based on some specific criteria.

Team composition is just one factor influencing teamwork effectiveness. Another factor is teamwork training. Engineering students should be educated about working in diverse teams to understand and accept the differences among team members [11], [13]–[16]. Additionally, team training should include how to conduct peer evaluation [17], and how to build trust [18]. Students should learn teamwork skills and knowledge, different team roles, time management skills, communication skills, and conflict resolution and leadership skills [19]–[27]. In the meantime, these skills have been investigated by several researchers [28]–[36].

Also, students should be aware of the common problems in teams, such as free riders, bias or team dysfunctionalities. Tenenberg [37] addressed the gap in engineering education literature about free riders, describing why the free-rider problem might happen in teams. Bias is another problem. For example, male engineering students might prefer male-typical speech over female-typical speech and evaluate them as the weak team members [38], or peer assessment might be biased base on students' race [39]. Anyway, any dysfunctionalities can be diagnosed by tools and innovative heuristics [40]–[42]. For finding the problems in teams, we need team member assessment and team performance evaluation.

These assessments can be implemented by collecting surveys about peer evaluation or team dynamics. Peer evaluation is a useful tool for formative and summative assessments and improves students' teamwork skills, academic performance, and students' learning [43]–[45]. Students might see peer evaluation as a good way to penalize free-riders or a chance to receive feedback [45]–[47]. Cinar and Biglin [48] suggested finding problems in teams by peer evaluation. However, there might be an inconsistency between peer-assessment and self-assessment [49], and this inconsistency might be addressed by several approaches [50], [51].

Yet peer evaluation is just an individual assessment, and team-level assessment is also essential for having effective teamwork. These assessments might be anything related to the team, such as quality of collaboration, an average of personality, experience, and academic performance in teams [11], [52], [53]. Team dynamics are another way to measure team performances. Trust,

conflict, and interdependence are well-known team dynamics in organizational behavioral psychology, and useful to be used in the context of engineering education [54]. However, engineering students and faculty pay less attention to team dynamics [55], and less research has addressed team dynamics in engineering education. Whitman et al. [56] reported that virtual teams have lower satisfaction comparing to non-virtual teams. Asio, Cross, and Ekwaro-Osire [57] found that the perception of teams' innovation differs based on teams' cohesion, conflict, and psychological safety. Teams in flipped classrooms have more satisfaction than non-flipped classroom teams, but they have similar levels of conflict [58]. Albeit psychological safety is a very important team dynamic for increasing team learning and can be used as a proxy for other team dynamics [59], [60], there is a gap in engineering education research to address psychological safety. To find a better understanding of psychological safety, we summarized the literature addressing psychological safety in other disciplines.

Psychological Safety

A high psychological safety in a team means the team members are feeling safe to take interpersonal risk, share their opinion [61], [62]. Psychological safety is considered the most important team dynamic to improve team performance by Google [63]. Psychological safety has some similarities with trust, but they are theoretically and conceptually different team dynamics. Psychological safety has only been measured as an individual's perspective about the environment in which they operate and whether they will experience negative consequences for contributing. Trust is a more general construct encompassing a willingness to be vulnerable and yield control without being able to monitor. It has been studied at both the team and individual level, whereas psychological safety is a common feeling about the entire team [64]. Psychological safety has been studied in different disciplines both quantitatively and qualitatively at the individual or team (aggregate/consensus) level [65].

If students feel psychologically safe in their team, they will learn more about team skills and knowledge [66]–[68]. Feeling psychological safety encourages team members to express their opinions and give team members better feedback [69]–[71]. There are further benefits associated psychological safety, which emphasizes the importance of having more research in this area in engineering education; psychological safety results in better commitment and motivation [72]–[75], reduces conflict [76], increases learning behavior [77], and decreases some problems typical of virtual teams [78]. More psychological safety creates an environment for learning from mistakes [79], [80]. Finally, psychological safety affects performance [81] and can mediate the relationship between high performance and implementing creativity [82].

Purpose of the Study

This study aims to address the gap in the literature in engineering education about the impact of psychological safety on the peer evaluation of each student's interaction in a team. A significant amount of literature tells us that interaction within a team is important, so finding ways to make interaction more effective is also important. So, finding any positive relationship between psychological safety and the level of interaction would highlight the need to make sure that students, teams, and classes are psychologically safe. To investigate these, we propose three research questions:

- How is a student's psychological safety related to the perception of the interaction of the team members?
- How is a team's average psychological safety related to the perception of the interaction of the team members?
- How is a class section's average psychological safety related to the perception the interaction of the team members?

Methods

Participants of the Study

Participants of this study are 1524 engineering students attending first-year engineering class in a large public university in the Midwest who participated in this study and answered all the survey questions. We had 392 teams and 14 sections. The gender frequency is summarized in Table 1.

Table 1. Gender frequency

Gender	Number	Percent (%)
Female	389	25.5
Male	1113	73
Other	22	1.5

Team Task and Context

All participants in this study engaged in the same 8-week project. Prior to starting the project, teams engaged in team-based activities as a whole team – developing a team flyer and a code of cooperation (similar to what others have called a team charter or a team contract). Each team member also engaged in pair programming with each teammate multiple times so that each dyad within a team had engaged in independent prior work experience before approaching the project as a complete team. The project itself was a modeling project using MATLAB with several milestones provided for scaffolding, but with a solution space that was sufficiently open-ended to allow teams to select a solution strategy and provide a rationale for their choice. As the project proceeded, teams were given additional objectives that required teams to modify their original approach—again, providing a rationale for any changes. The project task work includes diverse tasks—identifying an algorithm, specifying test cases, developing MATLAB code for the algorithm, testing the algorithm and debugging the code, and providing a written explanation of what the code does and a rationale for the choices made by the team. The project is designed to provide opportunities for each member of a four-person team to contribute, but can be reasonably completed with a three-person team in cases where a team started with three members or where one of the team's members withdrew from the class. Teams with only two team members are supplemented unless the team's members both request to continue working as a two-person team – and the instructor judges that to be a wise option.

Data/Variables

The data were collected using CATME, a web-based tool for team formation and peer evaluation [83]. Psychological safety as an independent variable was collected using Edmondson's [84] seven-item survey. This survey is available in appendix A, and the scale is from 1 (the lowest

psychological safety) to 7 (the highest psychological safety). Almost any study about psychological safety has used this seven-item survey [65]. Team members conducted peer evaluations that included an evaluation of an "*Interacting with Teammates*" dimension. We considered both self-evaluation and peer-evaluation, and we averaged the scores for each student to calculate our dependent variable, which is the perception of a student's interaction within a team (i.e. the quality of interaction each student has with team members). *Interacting with Teammates* is measured using a behaviorally anchored rating scale in which students read a set of desired behavior about interacting with teammates and select the set of behaviors that best describe how each teammate behaved throughout the rating period. Consistent with the typical analysis of BARS scale data, the rating is then converted to a numerical value from 1 to 5.

Analytic Strategy

To assess the relationship between psychological safety and a student's "Interacting with Teammates" score, we used a hierarchical multilevel model analysis. We wrote different models, starting with the unconditional means model (model 1):

$$\text{Interacting with Teammates}_{ijk} = \pi_{0jk} + e_{ijk} \quad (1)$$

where $\text{InteractingWithTeammates}_{ijk}$, the interacting with teammates of the i^{th} student in the j^{th} team in the k^{th} section, is modeled as a function of π_{ojk}, a team- level coefficient indicating the mean of student's "Interacting with Teammates" score of team j in the section k, and e_{ijk} is random error. The second level (team-level) coefficient π_{ojk} was also modeled as:

$$\pi_{0jk} = \beta_{00k} + r_{0jk} \quad (2)$$

In this model, β_{00k} is the third level (section-level) coefficient, which is the average level of student's "Interacting with Teammates (I)" score in the section k, and r_{0jk} is a team-specific error. The section-level coefficient β_{00k} was also modeled as:

$$\beta_{00k} = \gamma_{000} + \mu_{00k} \quad (3)$$

γ_{000} is the sample average level of student's "Interacting with Teammates (I)" score and μ_{00k} is a section level error. We used the unconditional model to estimate intra-class correlations (ICC) to evaluate the proportion of the variance in student's "Interacting with Teammates (I)" score for all levels.

In the following models, we added predictors to each level. We used student's psychological safety as the level 1 predictor (student level). The model (model 2) after adding level 1 predictor is:

$$\text{Interacting with Teammates}_{ijk} = \pi_{0jk} + \pi_{1jk}(Psychological\ Safety_{ijk}) + e_{ijk} \quad (4)$$

Team- level coefficients defined as:

$$\pi_{0jk} = \beta_{00k} + r_{0jk} \quad (5)$$

$$\pi_{1jk} = \beta_{10k} + r_{1jk} \quad (6)$$

And the third-level coefficients β_{00k} and β_{10k} defined as:

$$\beta_{00k} = \gamma_{000} + \mu_{00k} \quad (7)$$

$$\beta_{10k} = \gamma_{100} + \mu_{10k} \quad (8)$$

Similarly, we used the average psychological safety in teams as a team-level variable. The third model by team-level predictor is:

$$\text{Interacting with Teammates}_{ijk} = \pi_{0jk} + \pi_{1jk}(Psychological\ Safety_{ijk}) + e_{ijk} \quad (9)$$

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}\left(average\ Psychological\ Safety\ in\ Team_{jk}\right) + r_{0jk} \quad (10)$$

$$\pi_{1jk} = \beta_{10k} \quad (11)$$

The section-level coefficients $\beta_{00k,}$ $\beta_{10k,}$ and β_{01k} modeled as:

$$\beta_{00k} = \gamma_{000} + \mu_{00k} \quad (12)$$

$$\beta_{01k} = \gamma_{010} + \mu_{01k} \quad (13)$$

$$\beta_{10k} = \gamma_{100} \quad (14)$$

Finally, we used the average psychological safety in sections as a level 3 variable. The fourth model is:

$$\text{Interacting with Teammates}_{ijk} = \pi_{0jk} + \pi_{1jk}(Psycholoical\ Safety_{ijk}) + e_{ijk} \quad (15)$$

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}\left(average\ Psycholgical\ Safety\ in\ Team_{jk}\right) + r_{0jk} \quad (16)$$

$$\pi_{1jk} = \beta_{10k} \quad (17)$$

$$\beta_{00k} = \gamma_{000} + \gamma_{001}(average\ Psycholgical\ Safety\ in\ Section\ _{k}) + \mu_{00k} \quad (18)$$

$$\beta_{01k} = \gamma_{010} + \mu_{01k} \quad (19)$$

$$\beta_{10k} = \gamma_{100} \quad (20)$$

$\gamma_{000,}$ $\gamma_{100,}$ $\gamma_{010,}$ and γ_{001} are the sample average level of student's "Interacting with Teammates" score, main effect of psychological safety on the "Interacting with Teammates" score, main effect of average psychological safety in teams on the "Interacting with Teammates" score, and main effect of average psychological safety in sections on the "Interacting with Teammates" score, respectively. In addition, μ_{00k} and μ_{01k} are third-level errors (section-specific errors), respectively.

Results

After analyzing our models, we found that 57.05% of the variance in "Interacting with Teammates" scores was due to within-student (individual) differences, 40.45% of the variance to between-team differences, and 2.5% for within-sections differences. The individual-level predictor (a student's psychological safety) accounted for 0.5% of the within-students variation

in “Interacting with Teammates” score. The team-level predictor (average psychological safety in teams) accounted for 8.7% of the within-teams variation in “Interacting with Teammates” score. The section-level predictor (average psychological safety in sections) was not accounted for any of the within-sections variations in “Interacting with Teammates” score.

In the unconditional model, the random effects for the team-level were significant. So, the “Interacting with Teammates” score is significantly varying across teams ($p<.05$). At the section-level, the random effect was not significant, so, the “Interacting with Teammates” score is invariant across sections. In the second model, the psychological safety of students significantly influences the “Interacting with Teammates” score ($p<.05$) and the “Interacting with Teammates” score varies significantly by team ($p<.05$) and by student ($p<.05$).

Similarly, in the third model, the psychological safety of students and the average psychological safety of the team significantly affect the “Interacting with Teammates” score ($p<.05$). Students in teams with higher average psychological safety had higher “Interacting with Teammates” score.

In the final model, psychological safety of individual students and the average psychological safety in teams significantly influences the “Interacting with Teammates” score ($p<.05$). The fixed effect for the effect of average psychological safety on “Interacting with Teammates” score did not show a significant result,. so a higher average psychological safety in a section had no effect on “Interacting with Teammates” scores. See Table 2 for the full results of the last model:

Table 2

Estimates Three-level model for the effect of psychological safety on Interacting with Teammates score

	Interacting with Teammates score	
Fixed effects		
Intercept, γ_{000}	3.72**	(1.11)
Psychological safety of students, γ_{100}	0.04**	(0.01)
Average psychological safety of teams, γ_{010}	0.19***	(0.04)
Average psychological safety of sections, γ_{001}	-0.20	(0.20)
Random effects:		
Variance intercept team level, σ^2_{r0}	0.10***	(0.01)
Variance intercept section level, σ^2_{u0}	0.00	(0)
Variance linear slope (team psychological safety), σ^2_{u01}	0.00	(0.00)
Residual variance, σ^2_e	0.16***	(0.01)
–2LL	2022.4	

AIC	2028.4

Note. 1524 students nested in 392 teams and 14 sections. *AIC* = Akaike Information Criterion; –*2LL* = –2 Log Likelihood, relative model fit statistics. * $p < .05$, ** $p < .01$, *** $p < .001$.

To explain this result, the intercept represents the Interacting with Teammates score when the psychological safety is zero, which is not case here—3.72 on a 5-point scale. An increase of one point of a student's reported psychological safety will add 0.04 to that, and an increase of one point of the team's average psychological safety will add 0.19 to that.

Discussion and Conclusion

Psychological safety helps students to participate in team activities and learn from the teaming process. Due to the gap in the engineering education literature about impact of psychological safety on teaming, we conducted this study to find out whether the perception about the amount of a student's interaction in a team can be predicted by psychological safety of a student, average of psychological safety in teams, or average of psychological safety in a class section. Students who feel psychologically safe in their team are reported to have better interactions with other team members. This finding is similar to other findings in different disciplines than engineering. Also, students in teams with a higher average psychological safety tended to have better interaction within the teams. Based on these findings, we might say engineering students are willing to contribute to teams, listen to team members' ideas, encourage other team members, and ask for feedback if they work in teams with higher psychological safety. These findings are aligned with other findings in different disciplines than engineering [68]–[71], [81]. Since we are measuring the peer evaluation scores rather than real observation, the result might be biased because feeling psychological safety might motivate students to give a higher rating to their team members. However, even if this is the case, students still feel positive about their teams by having psychological safety, which might help them to have more chances for team learning [66]–[68]. Finally, in this study, we did not find a significant result related to the average psychological safety in the sections. It is possible that the lack of variability by the course section is a result of studying multiple sections of a coordinated course.

There are a few notable practical implications of our findings. Since there is no section effect, we can conclude that the presence of teams that have a lower psychological safety does not have the effect of suppressing interaction in other teams. This suggests that there is no need for section-wide instruction in psychological safety. The strongest effect is the team's average psychological safety, which means that even students who feel less psychologically safe benefit from being in a team that has a generally high psychological safety. This suggests that the most effective interventions will be at the team level, focusing on teams with a low average psychological safety.

Limitation and future study

In this paper, we used the peer evaluation rating of "Interacting with Teammates" to indicate the amount of interaction each student has in a team instead of an expert observation of a student's interactions. By including the self-rating in the peer evaluation, we may have introduced a bias for students with lower skills in the teams because, based on some literature, they might overestimate their rating [2], [85]. A follow-up study excluding self-rating would clarify this

issue. Whereas the average psychological safety of a team had a stronger effect on the Interacting with Teammates score than an individual's self-assessment of their psychological safety, individual psychological safety effects other important outcomes and is likely to be an important indicator of marginalization. Research along these lines is underway [86]. Also, the gender/race distribution was typical, but we didn't include that as a factor in the analysis. This means that the results are less likely to pick up the effects of marginalized groups. Finally, this study just analyzed the quantitative data, and having qualitative data would increase the significance of the study.

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Appendix A

Psychological safety measurement based on Edmondson questionnaire [84]:

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

And, here is the CATME rating scale for measuring the "Interaction with teammates":

			Description of Rating
○	○	○	• Asks for and shows an interest in teammates' ideas and contributions. • Makes sure teammates stay informed and understand each other. • Provides encouragement or enthusiasm to the team. • Asks teammates for feedback and uses their suggestions to improve.
○	○	○	Demonstrates behaviors described immediately above and below.
○	○	○	• Listens to teammates and respects their contributions. • Communicates clearly. Shares information with teammates. • Participates fully in team activities. • Respects and responds to feedback from teammates.
○	○	○	Demonstrates behaviors described immediately above and below.
○	○	○	• Interrupts, ignores, bosses, or makes fun of teammates. • Takes actions that affect teammates without their input. Does not share information. • Complains, makes excuses, or does not interact with teammates. • Is defensive. Will not accept help or advice from teammates.