Exploring an Intervention to Increase Psychological Safety on Student Engineering Design Teams

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Abstract

Psychological safety, or "the shared belief that a team is safe for interpersonal risk-taking" has been linked to positive outcomes on design teams including improved idea quality, improved learning behavior and knowledge creation, and higher job satisfaction. Research in other fields suggest that psychological safety may also contribute to team creativity and innovation which are important in engineering and design practice and education. Psychological safety has received growing attention in engineering design and education. However, research on interventions to increase psychological safety on engineering and design teams remains limited. Building on a previous Work in Progress paper, we tested an intervention based in improv theater designed to increase psychological safety on engineering design teams. In this work, we conducted an experiment using a randomized controlled trial design. Students from two different engineering courses were randomly assigned to teams of 4 students, and teams were randomly assigned to treatment and control conditions; treatment and control teams were assigned in both classes. We had 74 total participants on 21 teams. The intervention used in the treatment condition consisted of two exercises that we call "Yes, and" and "Thank you, because" which took a total of 26 minutes. Control teams completed parallel activities to ensure that all teams spent the same amount of time together. Following the intervention, participants completed a survey which included Edmondson's Team Psychological Safety Scale to compare results between the treatment and control groups. We conducted a Welch Two Sample t-test in R to compare team-level psychological safety between the treatment and control teams and found no statistically significant difference. Our findings suggest that our intervention either did not work or our sample size was too small to detect the effect of the intervention. We conclude by assessing why the intervention may not have worked and by outlining next steps for this line of work.

1.0 Motivation and background

Psychological safety has been defined as the "shared belief that a team is safe for interpersonal risk-taking" [1, p. 354]. Individuals on a team with high psychological safety feel comfortable being themselves, making mistakes, sharing ideas, and admitting failures [1], [2]. Prior research on psychological safety on engineering and design teams has shown that psychological safety is linked with improved idea quality [3], improved knowledge creation and learning behavior [4], [5], and increased job satisfaction [6]. Additional work outside of engineering suggests that psychological safety is related to additional outcomes important in engineering education such as enhanced team creativity and innovation [7], [8], [9].

Recent work has focused more specifically on psychological safety on student engineering design teams. Cole et al. [10] suggested possible factors that may influence a team's psychological safety, including communication, coordination, cooperation, composition, conflict,

creativity, and cohesiveness. In another study, Cole et al. [3] examined the relationship between psychological safety and idea generation, showing that psychological safety was positively related to the quality of ideas generated, but negatively related to the total number of ideas. Scarpinella et al. [11] investigated an intervention to increase psychological safety on student engineering teams, as outlined in the following section.

Other work on psychological safety in engineering education has considered the relationship between psychological safety and other team factors such as the gender of team members [12], [13], the presence of international team members [13], and team conflict/cohesion [14]. Additional work has examined psychological safety on senior capstone teams in engineering programs [15], [16] or in first-year engineering programs [17]. However, limited work examines potential interventions to develop psychological safety in these settings.

1.1 Methods to create or enhance psych safety

Despite the recognized importance of psychological safety on teams in a variety of fields, there are limited evidence-based interventions to build or increase team psychological safety. Some interventions have been evaluated and have not shown statistical significance (see [18], [19]), but others show promise. Some of these potentially promising interventions include a 10-week mindfulness-based intervention in various organizations [20], holistic facilitation sessions where team members can openly explore and discuss differences of opinion [21], and regular inquiry-based team debriefs facilitated by team leaders in the healthcare field [22]. These however tend to focus on long-term gains in psychological safety, which can translate poorly to educational environments with shorter-term lifecycles.

There are at least two interventions of interest that were either designed for an educational setting or that would translate well to one. Parker and du Plooy [23] implemented a team-based game known as the Marshmallow Challenge to develop team psychological safety, and their work showed significant results. In this intervention, participants receive 20 pieces of uncooked spaghetti, one meter of masking tape, a ball of wool, scissors, and a marshmallow, and are tasked with building a self-standing structure that holds the marshmallow at the top. This study found that psychological safety increased directly following this challenge, though the study was not experimental so could not conclusively show that the activity increased team psychological safety.

Scarpinella et al. [11] developed and experimentally tested an intervention specifically with engineering design teams. In their intervention, they provided a 10-minute video on psychological safety, 3 shorter 3-5 minute videos on how to develop psychological safety during the design process, and included time for participants to practice strategies for developing psychological safety. They found that psychological safety was higher for the intervention groups than the non-intervention groups at the final time point in their data collection. The more recent promising studies combined with the persistent challenges in developing an intervention that can have an immediate impact show that additional work needs to be done in this area.

1.2 Improvisational training and psych safety

Improvisational training (improv) is adapted from improvisational theater and improvisational comedy, and this work builds on a previous Work in Progress paper that outlined a framework and theory of change for an improv intervention [24]. Improv training has been used more broadly to improve communication skills [25], [26], divergent thinking [27], [28], teamwork [29], and to develop intra- and inter-personal skills [30]. Further, limited qualitative research suggests the opportunity for improv to develop team psychological safety [31]. There are seven key tenets of improv [32] as outlined in Table 1. Thus, in this study, we test an improv intervention to enhance team psychological safety.

Table 1. The seven tenets of improv and their definitions, reprinted from [24] with permission

Seven tenets of improv [32]	
1. Yes, and	"Accepting what's offered and adding to it" [32, p. 25]
2. Ensemble	Working with others as a whole where there is no "need to be right, need to steal focus, or need to appear in control" even if you're not [32, p. 14]
3. Co-creation	Creating new things together and "seeking suggestions, monitoring feedback, and transforming material in turn" [32, p. 14]
4. Authenticity	"Dare to offend. Be unafraid to speak to power, to challenge conventions, and to question the rules" [32, p. 15]
5. Using failure	"We fail in order to create"[32, p. 145]
6. Follow the follower	"No one leads, and no one follows – everyone in the group is constantly shifting…the leading and the following are constantly in flux" [32, pp. 167–168]
7. Listening	"To truly hear and value others' ideas" [32, p. 197]

2.0 Methods

The research question addressed by this study is *does an improv-based intervention consisting of "Yes, and" and "Thank you, because" exercises increase psychological safety on student engineering design teams?* We conducted an experiment using a hybrid of cluster randomized control design and randomized block design to test the psychological safety intervention on student engineering teams. Participants were students in two different engineering courses (details in the Participants section below). In each class, students were randomly assigned to teams of 4 students (with two teams of 6 due to the number of participants), and teams were randomly assigned to treatment (psychological safety intervention) or control. The purpose of this study was to pilot the intervention and procedure for a larger study. This research was approved by the University of Virginia's Internal Review Board under protocol IRB-SBS #4752.

2.1 Participants

Participants were students in two different upper-level engineering courses in the Department of Systems Engineering and the Environment at the University of Virginia: Behavioral Design and Introduction to Systems Engineering and represent a convenience sample. There were 92 total participants assigned to 21 different teams. Results from participants who did not complete both

surveys were excluded. The total sample was therefore 74 students on 21 teams. Table 2 shows a basic summary of participant characteristics, and Table 3 provides a balance table comparing participant characteristics between the intervention and control groups. The sample size is too small to expect perfect balance between samples; the largest difference was in the percentage of white participants in the two groups.

Table 2. Summary of basic participant characteristics

Characteristic	Response	Count
Age	Years, mean	23.8
Sex	Male	38
	Female	34
	Other	1
	Prefer not to say	1
Race	Asian	11
	Biracial	9
	Black	5
	Latinx	4
	Mid-African	4
	Prefer not to say	0
	White	41

Table 3. Balance table showing demographic characteristics for the treatment and control groups

Characteristic	Response	Percent (count), treatment	Percent (count), control	Difference in percentage points
Sex	Male	53.5% (*n*=23)	48.4% (*n*=15)	5.1
	Female	44.2% (*n*=19)	48.4% (*n*=15)	4.2
	Other	2.3% (*n*=1)	0% (*n*=0)	2.3
	Prefer not to say	0% (*n*=0)	3.2% (*n*=1)	3.2
Race	Asian	14.0% (*n*=6)	16.1% (*n*=5)	2.1
	Biracial	14.0% (*n*=6)	9.7% (*n*=3)	4.3
	Black	9.3% (*n*=4)	3.2% (*n*=1)	6.1
	Latinx	4.6% (*n*=2)	6.5% (*n*=2)	1.9
	Mid-African	7.0% (*n*=3)	3.2% (*n*=1)	3.8
	Prefer not to say	0% (*n*=0)	0% (*n*=0)	0
	White	51.1% (*n*=22)	61.3% (*n*=19)	10.2

2.2 Procedure

When students arrived to class on the day of the study, they first signed in; this sign-in document was used to randomly assign students to teams. Next students completed a survey (survey 1), which began with IRB consent and included demographics questions. Students then found their teams and began a set of team activities, following written instructions that were emailed to each student. All students on the team introduced themselves by sharing their name and program of study. Following team introductions, each team spent 26 minutes completing either the intervention or the control activities as described below. After the team activities, all participants completed a second survey, which included Edmondson's 7-item measure of psychological

safety [1] and an open-ended text response where participants were able to share any comments or feedback.

2.2.1 Intervention and control exercises

The intervention consisted of two separate exercises that we call "Yes, and" and "Thank you, because." Details for each of these exercises along with their control counterparts are below. All teams in both conditions spent roughly 26 minutes with each other; this was designed to account for the possibility that psychological safety may increase by simply spending time together. Four of the seven tenets of improv are addressed by the intervention, and Table 4 shows how these tenets map to aspects of psychological safety.

Table 4. How the tenets of improv map onto components of psychological safety. Adapted from [31]

	Edmondson's Psychological Safety Components [1]		
Leonard and Yorton's Improv Tenets [32]	*Confidence that team won't embarrass, reject, or punish for speaking up*	*Interpersonal trust and mutual respect*	*Letting go of thoughts of negative consequences of expressing ideas. Being oneself.*
Yes, and:	Affirming and building Setting up the next person for success	People care about one another and try to support each other's efforts Trust is given as a gift	Less judgment Remove filters Experimentation and tolerance of mistakes
Ensemble & co-creation	All ideas are good ideas Letting go of competition and hierarchy	Finding the idea, not your idea Group's goals trump individual goals Asking questions Willingness to change	Willingness to change Eradicating fear
Listening	Mindfulness Presence in the moment Empathy	Ability to read non-verbal cues Listening to understand	Requirement to contribute freely Deep listening requires focusing on the other rather than yourself

2.2.1.1 "Yes, and" intervention

The "Yes, and" exercise was developed based on the first tenet of improv, "Yes, and" along with a common "Yes, and" activity from improv training. In this activity, participants experience the

feeling of affirming and building upon others and having their own responses be affirmed and built upon. This activity was designed to take roughly 10 minutes. Students were told to work with their team to plan a vacation. The following instructions were provided for the intervention teams.

Work with your team to plan a vacation. This is entirely fictional; there are no limitations on what you can do.

Round 1: Yes, but (2 minutes)

- The team member with the **first** name alphabetically (by first name) begins.
- This person shares an idea for a vacation.
- Moving clockwise, the next team member responds "Yes, but…" and replies to the previous person.
- Continue moving clockwise and having each team member respond "Yes, but…" for a total of 2 minutes.
- **Each contribution must be a statement. Do NOT reply with a question.**
- *Example:*
    - *Teammate 1: Let's go to the beach.*
    - *Teammate 2: Yes, but I don't like the sand.*
    - *Teammate 3: Yes, but you can wear shoes.*
    - *And so on...*

Round 2: Yes, and (2 minutes)

- The team member with the **last** name alphabetically (by first name) begins.
- This person shares an idea for a vacation.
- Moving counterclockwise, the next team member responds "Yes, and…" and replies to the previous person.
- Continue moving counterclockwise and having each team member respond "Yes, and…" for a total of 2 minutes.
- **Each contribution must be a statement. Do NOT reply with a question.**
- *Example:*
    - *Teammate 1: Let's go to the beach.*
    - *Teammate 2: Yes, and we can bring our favorite foods to eat.*
    - *Teammate 3: Yes, and we can go swimming.*
    - *And so on...*

Debrief (4 minutes)

- Discuss your experience with these two exercises with your team. How did they make you feel? Which exercise did you prefer? Why?

2.2.1.2 "Yes, and" control

The control counterpart for the "Yes, and" exercise was similarly designed to take 10 minutes, and focused on planning a vacation, but it removed the aspect of affirming and building upon

previous teammate's suggestions by focusing on individual contributions. The following instructions were provided for the control teams.

Each team member will take 2 minutes to share their dream vacation. This is entirely fictional; there are no limitations on what you can do.

- Person responsible for timing starts timer.
- The team member with the **first** name alphabetically (by first name) begins.
- This person shares their dream vacation.
- Person responsible for timing stops the individual after 2 minutes.
- Moving clockwise, the next team member shares their dream vacation. (If on Zoom, the first team member should call out the next team member on their screen.)
- Repeat for each team member

2.2.1.3 "Thank you, because" intervention

The "Thank you, because" activity was developed based on an exercise researchers have used in executive training sessions in partnership with a large improv organization [33]. Since this exercise is not yet published, we provide a high-level overview of the activity rather than the specific details. The activity was designed to take 16 minutes. In this activity, participants were put into pairs. They then completed a 15-item questionnaire rating the extent to which they agree with each item, where each item is a potentially polarizing topic (e.g. "Children under 12 years old should NOT be allowed to use cell phones.") Participants then compared scores and identified the topic where they had the biggest difference in score, and therefore the topic where they disagreed the most.

Participants were then told to have a conversation about the topic while focusing on "appreciating how your conversation partner's point of view contributes to the conversation by telling them what you value or appreciate about hearing their point of view." Participants were given a sample conversation on a different topic to provide an example of how the conversation might go, and they were given 4 minutes to have the conversation, followed by 4 minutes to debrief with their entire team about their experience with the exercise.

2.2.1.4 "Thank you, because" control

In the control activity for the "Thank you, because" part, participants were told to debate with their partner whether "social media has helped or hindered human communication." Participants were similarly grouped into pairs for this discussion and were provided a similar sample conversation for reference. They were given 4 minutes for the conversation with their partner and 4 minutes for a debrief with their team. Since participants did not need to take the same survey as in the intervention group, this exercise did take slightly less time – participants were given 10 total minutes for the exercise.

2.3 Psychological safety measure

Edmondon's 7-item measure of psychological safety was used to determine team psychological safety [1]. This is the most commonly used measure of psychological safety [34]. This measure includes 7 items that each team member answers individually, as outlined in Table 5. 3 of the 7 items are reverse-coded in subsequent analysis. Individual responses to the 7 items are averaged to an individual psychological safety score between 1 and 7. These individual scores are then averaged to a team-level psychological safety score. This measure has been shown to be meaningful at the team level in previous work with an intraclass correlation of 0.39 [1].

Table 5. The seven questions to measure psychological safety. Starred items are reverse coded.

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

3.0 Analysis

We conducted a Welch's two sample t-test in R to assess whether the intervention worked by comparing team psychological safety scores between the intervention and control teams. We used Welch's two sample t-test because it handles unequal sample sizes and unequal variances better than the Student's t-test, and has been recommended as a better default t-test [35].

4.0 Results

The average team psychological safety for the treatment groups was 6.07 and the average team psychological safety for the control groups was 6.20. This is the opposite of what we would expect, however the difference was not statistically significant based on the Welch Two Sample t-test; the *p*-value was 0.485 with a 95 percent confidence interval of [-.0238, 0.483].

5.0 Discussion

There are a number of reasons as to why the intervention may not have worked as intended, including insufficient sample size, aspects of the intervention design and implementation, and logistical challenges, which we discuss below.

5.1 Insufficient sample size

The most straightforward possible explanation is that the sample size may have been too small to actually detect a difference between the treatment and control groups. This is definitely a

possibility, since a sample size of 21 teams and 74 individuals is small for a team-level measure. It can be challenging to determine required sample size for a team study as opposed to one focusing on individuals [36]. Assuming that 1 team in this study is the equivalent of 1 individual in an study where the individual is the unit of analysis (which is likely a conservative assumption), GPower calculations suggest that the total sample size required to detect a medium effect size (d=0.5) is 176 and the total sample size required to detect a small effect size (d=0.2) is 1084 [37]. This is based on the t-tests test family, the Means: Difference between two independent means (two groups) statistical test, α=0.05, *power*=0.95, and an equal number of participants in the two groups. Effect sizes for these types of short improv interventions are often in the d=0.25-0.75 range (see [27], [38], [39], [40] for examples, though they're related to divergent thinking rather than psychological safety), so it is likely that this was at least one reason why there was not a statistically significant difference between the treatment and control groups.

5.2 Intervention was too complicated

The qualitative feedback that participants provided and our observation of the study suggest that either the intervention was too complicated, the study required more active facilitation, or a combination of the two. Participants shared that they "needed more clear direction" or that the instructions were "unclear" or "difficult to navigate," which was helpful feedback considering the purpose of this study was to pilot these processes. However, this also probably contributed to an ineffective intervention. The "Yes, and" portion of the study was fairly straightforward, but the "Thank you, because" portion could likely have used additional facilitation. One student, for example, shared their experience, where their partner for the "Thank you, because" activity did not take the exercise seriously and was ridiculing their responses in the structured discussion. This suggests that in some cases, the "Thank you, because" part of the intervention may have backfired.

In future work, the intervention can either be streamlined or more actively facilitated. The exercise that we adapted this from, for example, had a detailed minute-by-minute facilitation script that we were not able to follow due to space and time constraints in the classrooms; following this or a similar script with a facilitator keeping track of timing and verbally sharing instructions every couple of minutes may help by providing an additional set of instructions (verbal in addition to the written ones) and by helping to better set the tone and expectations for the exercise.

5.3 Psychological safety was high for all teams

The teams in this study seemed to have been feeling highly psychologically safe in general. Ratings in all conditions were in the range of 6 on a 7-point scale. It is possible that since this experiment was conducted at the end of the semester that students had gotten to know each other and that their psychological safety ratings were thus bolstered by a semester of positive experiences. Additionally, the control activity for the thank you, because exercise may not have

required meaningful disagreement, and may have led to increased levels of psychological safety within the control group as a result, thus unintentionally bolstering psychological safety on the control teams.

Future work can address this by running experiments earlier in the semester. Additionally, the thank you, because intervention could be compared to a control group that requires disagreement but does not provide a constructive way to handle this disagreement; this could lead to a wider range of team psychological safety scores.

5.4 Intervention didn't focus enough on interdependence of team members

Another potential reason why the intervention did not work is that the intervention activities might not have focused enough on interdependence of the team members. Since psychological safety is a team construct, interdependence may be an important component of developing team psychological safety. While the "Yes, and" exercise was completed as a group, the procedure made it more of a dyadic activity since each person was building on the previous suggestion. The "Thank you, because" exercise was even less of a team activity since it required dividing groups into pairs. While these activities may have set some group norms, the true interdependence of team members may not have been developed. Future interventions can enhance the interdependent nature of activities. There are different exercises from improvisational theater that cultivate more of a team environment. For example, "Family portrait" is an activity where each group is given a title for a photo of a type of family, like "Family of Cats" or "Family of Professors." The group then has 10 seconds (or less) to physically form a "portrait" based on the title (see [41], [42]). This might emphasize the interdependent nature of the team more, though there are trade-offs with how comfortable or uncomfortable participants may be with a more physical or active exercise.

5.5 Intervention activities were not engineering-focused

Another aspect of the intervention design that may have impacted its effectiveness is that the two components of the intervention were not focused on engineering topics. This may have made the exercises feel a bit out of place in the engineering classroom, as several participants noted, and may have detracted from how realistic or relevant they seemed for participants. It may be worth tweaking the exercises to have more of an engineering focus in the future to address this potential issue. This could be done by using "Yes, and" on an engineering topic, like a brainstorm session, and by changing possible topics in "Thank you, because" to be common topics of discussion or disagreement in the engineering field.

5.6 Logistical challenges

There were several logistical challenges that likely impacted the study as well. First, in one of the classes, the study was conducted on the last day of class. In the other class, it was the third to last day of class. It is possible that these participants were less engaged and wanted to just check the

box to be done with the semester. In the future, it may be helpful for us to explicitly ask participants how engaged they felt as a way to assess their buy-in for the study.

Additionally, one of the classes was a hybrid in-person/virtual class, due in part to Covid-19 circumstances, which created additional challenges for facilitation and building team rapport. Rather than create teams of all online and all in-person students, the teams ended up having a combination of in-person and online students based on our approach to random assignment. Several students commented on the challenging nature of these teams in the feedback comment box in the survey, sharing that "doing this over Zoom and in person makes it more challenging" and that "it would have been better if groups had been drawn from in-person and online classmates separately." For future work, we will focus more intentionally on exploring interventions either in-person or virtual settings rather than combining them into a single study.

6.0 Conclusion

Psychological safety is a construct that shows promise as a team characteristic that could lead to both improved engineering outcomes and improved learning outcomes. Some of the interventions that have been shown to increase psychological safety focus on longer term interventions and timeframes which may not fit in a shorter term, educational setting. In this study, we tested a 26-minute improv intervention designed to fit in a single class period. This intervention did not boost psychological safety in this study, though there are a number of possible reasons why it may have failed in this case.

Future work could address many of the concerns presented in this paper. For example, improving the level of facilitation, adapting the topics of the intervention to be more engineering focused, and modifying the activities to require more team interdependence may increase relevance and prevent unintended consequences of the intervention. It would also be beneficial to test future psychological safety interventions with a larger sample size. However, in future studies with smaller sample sizes, additional sources of data, such as interviews, may help add depth to our understanding of why a particular intervention may or may not have worked.

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