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LET'S ROLE PLAY! THE IMPACT OF VIDEO FREQUENCY AND ROLE PLAYING ON THE UTILITY OF A PSYCHOLOGICAL SAFETY TEAM INTERVENTION

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ABSTRACT

There is growing evidence on the importance of psychological safety, or how comfortable participants feel in sharing their opinions and ideas in a team, in engineering team performance. However, how to support it in engineering student teams has yet to be explored. The goal of this study was to investigate whether a video intervention with assigned roles could foster psychological safety in student engineering teams. In addition, we sought to explore the impact of the frequency of the videos and the utility of the roles on the self-efficacy of students and the perceived psychological safety of the team. Specifically, this study introduces video interventions and the four lenses of psychological safety (Turn-Taking Equalizer, Point of View Shifter, Affirmation Advocate, and Creativity Promoter), and seeks to determine their effectiveness at increasing psychological safety self-efficacy and individual levels of psychological safety. A pilot study was completed with 54 participants (36 males, 17 females, 1 non-binary/third gender) enrolled in a cornerstone engineering design course. Over 10 weeks, data was collected at 5 time points. The results present four key findings. Most notably, 1) a video educating all students about psychological safety in general was effective in improving psychological safety self-efficacy and students retained this information to the end of the project;2) intervention groups taught to use the four lenses did not have a statistically significant higher level of psychological safety than non-intervention groups; and 3) intervention groups perceived the use of the lenses to increase psychological safety. These results provide a baseline understanding that is needed to support psychological safety including: when to intervene, how to intervene, and how frequently to intervene.

Keywords: design theory and methodology, design methodology, design education

INTRODUCTION

Teams are often used throughout engineering due to the widespread belief that teams are able to generate solutions to complex problems more effectively than individuals alone [1, 2] because the team is greater than the sum of the individual team members [3, 4]. Working in teams, as compared to working individually, expands knowledge, increases creativity and results in previously unimagined solutions [5]. However, according to Deloitte's 2019 Global Human Capital Trends report, of 10,000 respondents in 119 countries, only 31% “operate mostly or almost wholly in teams” with 65% working “mostly hierarchical[ly] but with some cross-functional team-based work” ([6], p. 8). The report concludes in part that current leaders do not know how to adapt and “operate” in teams ([6], p. 8). As more organizations recognize the need to shift to team-based work, understanding how to encourage and maintain positive team dynamics will be essential to a team’s success.

A critical aspect of working together involves fostering psychological safety or a “shared belief held by members of a team that the team is safe for interpersonal risk taking” ([7], p. 350). In other words, psychological safety within teams is a measure of the comfort members hold in sharing their opinions and ideas. A higher level of psychological safety results in improved team dynamics, which is directly related to improved team performance [8]. Greater team member confidence leads to increased sharing of ideas and new perspectives on problems that can bring about cutting-edge solutions. Limited research has been completed concerning psychological safety as it relates to engineering. However, there is evidence of a direct relationship between positive team dynamics, performance, and resulting creativity in engineering teams ([9], p. 17).

One method of inspiring psychological safety is the use of controlled team interventions. Controlled team interventions consist of interference by a third party, such as a professional facilitator, or imposing a new training procedure, process review, or other similar protocol [10]. Interventions have been shown to increase a team’s psychological safety and thereby improve team effectiveness and overall performance [10–12]. Studies of team interventions have previously been focused on the healthcare sector and not the engineering discipline. However, when, how, or how often to intervene to successfully facilitate psychological safety in teams has yet to be investigated.

In light of prior work, the goal of this study was to explore the best means of supporting psychological safety in engineering education through an intervention. Specifically, we focused on the utility of two key intervention elements: short videos and role playing. Two conditions were used in the current study to identify the utility of a single intervention (video at start of project) versus a repeated intervention with role playing. The results of this study provide evidence on the utility of videos and role playing for supporting psychological safety and provide a baseline from which to develop successful team interventions in engineering education.

RELATED LITERATURE

In recent years, psychological safety has gained significant traction in the workplace [13]. The study of psychological safety began in the 1960s, resurfaced in the 1990s, and has grown in importance in the last 10 years [13]. This increase can be explained by society’s greater understanding and emphasis on what psychological safety is, and the effect it can have on teams. Psychological safety has been shown to be a predictor of team dynamics, performance, and innovation, by enhancing the team’s ability to communicate and problem solve [5, 7, 13].

The study of psychological safety and team performance has been focused in areas such as healthcare [14], manufacturing [7], geographical dispersion [15], innovation [16], user interface design courses [17], and software development [18–20]. These studies reinforce time and time again the benefits of psychological safety in teams.

Research completed concerning psychological safety in engineering teams, though limited, corroborates the relationships found in non-engineering teams related to psychological safety and its positive impact [18]. Specifically, in engineering teams, “interdependence, role clarity, and a supportive work setting are positive predictors of psychological safety” ([18] p. 9, [21]). In addition, high psychological safety in engineering teams leads to a greater quality in the ideas developed and greater acceptance of those ideas [19].

Creating psychological safety within teams has become increasingly important. Prior studies have investigated factors which promote psychological safety. These studies have concluded that psychological safety is improved through effective communication, trust, and social support [5, 22]. The length of time in which team members interact is also an important factor in increasing psychological safety [18]. Similarly, self-efficacy, or the belief that someone “has the knowledge, skills, or competence required to achieve specific goals or objectives,” ([23], p. 2) is improved when information is repeated over time [23, 24].

Fostering psychological safety in the workplace with engineering and non-engineering teams has become both more difficult and more important with the onset of the COVID-19 pandemic. Developing safe interpersonal relationships is more difficult when team members are working remotely and team conversations are infrequent and more formal [25]. At the same time, remote work is increasingly desired, and a survey by McKinsey & Company reports that “52% of workers would prefer a more flexible working model postpandemic” [21]. Consequently, additional actions need to be taken now in both the engineering and non-engineering contexts to boost psychological safety in the remote work setting and avoid a decrease in team performance.

Team interventions have been used to promote psychological safety among group members. Thus far, team intervention research has been focused in the healthcare industry where interventions have been found to increase adaptability [26] and reduce employee errors [27], a vital concern in healthcare. When members of healthcare teams feel more comfortable speaking up, they are able to engage in effective conflict and produce more diverse solutions [26]. Various types of interventions have been used by healthcare providers, including employing in-person professional facilitators, imposing new training procedures and performing in person process reviews [10–12].

Minimal research has been completed examining the effectiveness of interventions on engineering teams. A study conducted by Dusenberry and Robinson explored the impact of a video lecture intervention. That study involved giving a series of five video interventions to students (including engineering students) one after the other in immediate succession (not over time) [28]. These video interventions taught the students ways to improve psychological safety by “address[ing] the sharing of one’s personal self, the importance of being oneself, understanding team conflict and resolution, and team norms” ([28], p. 214). Results confirmed that groups given the intervention videos had elevated psychological safety averages compared to groups that had not viewed the videos [28].

While not related to psychological safety, role assignment, or role playing as a type of team intervention, has been found to increase group focus, develop a greater understanding of the discussed topics, encourage creative ideas, and postpone judgment [29]. In practice, appointing team members to take on roles like Team Leader, Work Organizer, Ideas Generator, Researcher and other traditional roles leads to more favorable team dynamics [27]. Team performance is improved, with teams showing better communication and presenting results earlier [30]. Role assignments have also been found to aid team members when facing conflict, by giving members the necessary skills and tactics to resolve problems [31]. For example, Beranek et al. examined software engineering students, finding that both “task-oriented” role assignments and “positive group atmosphere” role assignments were important in creating an effective team [32]. Role assignment interventions have also been explored in non-engineering teams with results showing that certain types of role assignment in diverse teams (with diversity stemming from gender and educational major) can lead to greater team effectiveness and performance [33, 34]. However, the assignment of roles has yet to be explored in the context of psychological safety.

The current study extends prior research on engineering teams by combining video interventions over a period of time with role assignments. As such, this study looks to understand the effect of role-focused video interventions given over time, throughout the engineering design process, on psychological safety in student engineering teams. The engineering design process has three main phases: concept generation, concept screening, and communication [35–37]. More specifically, the engineering design process can be broken down to five time points: start of project, concept generation, concept selection, low-fidelity prototypes, and final deliverables [19, 36]. Video interventions with role assignments were given prior to each of the five time points in the engineering design process. Using these video interventions with college engineering students provided participant flexibility and enhanced the usefulness of the study for the increasingly popular remote working scenarios. For example, video interventions can be administered to large populations of in-person or virtual members of the workforce and college students. Furthermore, using student engineering teams provided an opportunity to work with complex teams of people who have likely not had extensive group project experience. This allowed the intervention’s impact (or lack of impact) to be more easily assessed.

THE LENSES

In our study, team members in the intervention were assigned roles, or lenses, designed to foster psychological safety. Role clarity within a team has been shown to increase psychological safety [21], and the roles in this study were created to be tested on engineering students. The roles used in the study are described below, along with their role titles, responsibilities, and suggested conversation questions and affirmations. The team member roles were presented to the engineering students in video format, and these interventions were given at various time points as described in the Procedure section.

The **Turn-Taking Equalizer** role was tasked with proactively providing input to make sure critical feedback is given on design ideas the team has developed. This role is important because if a team member is not providing feedback the team may miss out on critical or supportive feedback that the team needs to make the best decisions. Encouraging turn taking has shown to increase team involvement, inclusiveness, and team performance [38]. Suggested questions the Turn-Taking Equalizer can ask include: “We need to hear from you,” “What are your thoughts on this?” and privately, “how can I help you contribute to the discussion today?”.

The team member with the role of **Point of View Shifter** was responsible for giving alternate perspectives on design ideas. This is important for concept selection because the Point of View Shifter makes sure the team is considering both critical and supportive views of the design ideas. Asking critical questions to team members can lead to more thoughtful discussion and enhance learning [39]. If the team is only sharing positive views on designs, suggested questions include: “who has a different perspective?” or “what are we missing about this design?” If a team member is being overly critical, suggested questions include: “what are some good aspects of this design?” or “how could we make this idea work?”.

The goal of the **Affirmation Advocate** role was responsible for listening to, respecting and showing interest in comments, affirming every member’s contributions. Total silence should be avoided after members provide their input, because silence may make team members less likely to say something next time. It is important for team members to feel their contributions are welcome so that all team members will feel comfortable in the future. Reciprocal affirmation is important to effective teamwork [40]. Suggested positive affirmations include: “that was a good point,” or “thank you so much for bringing up that point.” If a team member provides a critical or unpopular opinion, it is very important to support that team member. A suggested affirmation is: “that’s a unique perspective we needed to hear!”.

Finally, the goal of the team member with the **Creativity Promoter** role was to ask questions that help the team continue to develop ideas and support creativity. Encouraging further discussion can evoke creative ideas that go beyond what was previously mentioned [39]. Suggested questions include: “what two of these ideas could we combine together in a unique way?”, “what other ideas could we generate,” or “how can we build off of this idea to make it more novel?”. If someone is being overly critical of a design, a suggested question is: “what are some good aspects of this design that we could build on?”

While these lenses were developed to support psychological safety, their utility in the engineering design process has yet to be explored - anchoring the current investigation.

RESEARCH OBJECTIVES

The objective of the current study was to understand the impact of video frequency and the use of assigned roles on psychological safety in engineering student teams. Specifically, the following research questions (RQs) were explored:

RQ1: What impact do the video interventions have on psychological safety self-efficacy? Is there a difference between the lens and non-lens group?
Our hypothesis was that students who received the video interventions using role assignments would achieve a higher psychological safety self-efficacy at the end of the project. Research by Dusenberry and Robinson [28] confirmed that video interventions can improve psychological safety, but their work did not involve role assignments over time. In addition, Beranek and his associates found a positive impact on team dynamics from role assignments, but did not study psychological safety or video interventions [29, 32]. Our hypothesis extended the findings of both of these studies by examining the impact of video interventions with lenses, or role assignments, on psychological safety. Since both groups started at the same baseline, it was expected that the intervention and non-intervention groups early in the design process would have the same psychological safety. However, since the intervention group used the lenses throughout the project, we anticipated that the frequency of presentation and use of the lenses would positively affect self-efficacy [23, 24].

RQ2: Was there a perceived psychological safety difference in the intervention and non-intervention group?
Our hypothesis was that students who received the interventions would achieve a higher perceived psychological safety. Dusenberry and Robinson’s work demonstrated that video interventions about psychological safety improved psychological safety [28], and Beranek’s work showed that team roles help team members develop creative ideas, postpone judgment [29], and effectively resolve conflict [31]. Since a higher level of psychological safety means team members feel more comfortable sharing their ideas, resulting in improved team dynamics and overall team performance [8], we hypothesized that team roles taught through video interventions would result in a perceived psychological safety difference between the intervention and non-intervention groups.

RQ3: How did the perception of the utility of video interventions change throughout the project?
Our hypothesis was that students would perceive the utility of the video interventions to be increasingly beneficial over time resulting in an increase in psychological safety ratings over time. Prior literature suggested that the belief that someone “has the knowledge, skills, or competence required to achieve specific goals or objectives,” ([23], p. 2) is improved when information is repeated over time [23, 24]. Considering a student’s learning curve and that psychological safety develops over time [18], it was expected that students would view the video interventions as more effective over time.

RQ4: How did the perceived usefulness of the Lenses of Psychological Safety change throughout the design process?
Our hypothesis was that students would find certain team-intervention lenses more useful at certain phases of the design process. Broken down to five stages, the engineering design process consists of the start of project, concept generation, concept selection, low-fidelity prototypes, and final deliverables [19, 36]. Cole et al. found that psychological safety during the concept generation process (TP3) was not significantly related, and psychological safety did not influence the number of generated ideas [19]. However, given what is required in the stages (as described in the Methodology section) and what the lenses provide, we expected the Turn-Taking Equalizer and Point of View Shifter to be most useful during concept selection; Creativity Promotor to be most useful during concept generation, and Affirmation Advocate to be most useful throughout the whole project.

METHODOLOGY

To answer the research questions presented, a 10-week study was conducted in Spring of 2021 at a large northeastern university in two class sections of a first-year engineering design course. The rest of this section lays out the methodology for this study.

Participants

Fifty-four participants (36 males, 17 females, 1 non-binary/third gender) between the ages of 18 and 24 participated in the study. The participants were enrolled in an in-residence first-year cornerstone engineering design course.

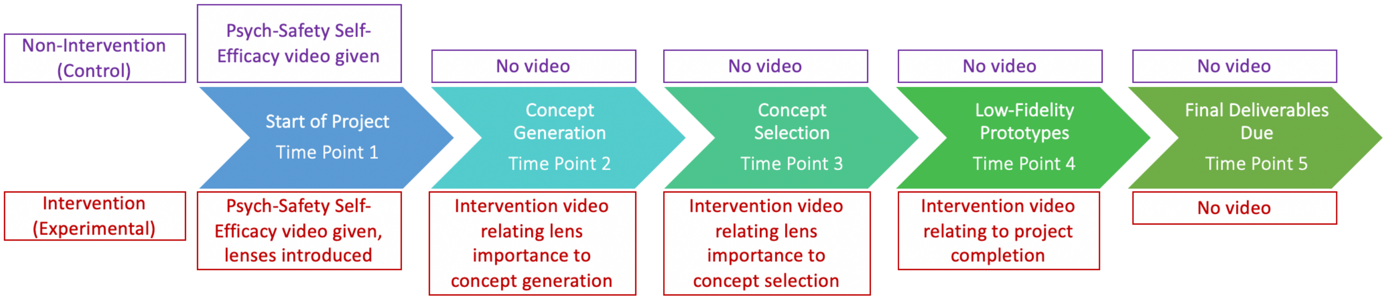

Figure 1: TIMELINE OF STUDY- PSYCHOLOGICAL SAFETY WAS CAPTURED AT THE END OF EACH TIME POINT AND SELF-EFFICACY CAPTURED DURING TIME POINT 1 AND TIME POINT 5 (TOTAL TIME PERIOD 8 WEEKS)

Procedure

This study was performed during the spring semester of 2021 with a virtual, synchronous section of a first-year cornerstone engineering design class. Students were required to complete a team project over the course of 10 weeks and were provided the opportunity to voluntarily participate in the study according to the Institutional Review Board processes. Specifically, two class sections were studied, with one section given the intervention lenses (the experimental group of 8 teams) and the other section not given the intervention lenses (the control group of 8 teams). The two sections were taught by the same instructor. Figure 1 depicts the study timeline. Specifically, the study proceeded as follows:

At ***Time Point 1 (TP1)***, participants were grouped in 3- and 4-person teams. After teams were created, and at the start of class, the participants were asked to complete a *Psychological Safety and Self Efficacy Survey* that asked participants about their current knowledge of psychological safety, factors that contribute to psychological safety, and how to build psychological safety, see Metrics Section for further details. Following completion of the initial survey, students were shown a video about psychological safety that introduced students to the concept and generally how to support it in their team. However, students in the intervention group were shown a slightly longer (~3 minute) video than the control group that also contained information on the Lenses of Psychological Safety described in The Lenses Section to improve psychological safety [41]. At the end of the video, students in the intervention group were asked to assign each team member one of the roles for the remainder of class. The teams were then introduced to a design challenge by the instructor and researched the design problem for the rest of class as a team. Finally, at the end of the class period, both groups completed a second *Psychological Safety and Self Efficacy Survey* which included one additional item about the perceived psychological safety of the team. The intervention group condition also completed four additional questions about the *Lenses of Psychological Safety*.

During ***Time Point 2***, teams were prompted to develop their problem statements. The experimental group was shown a second video about the lenses of psychological safety as they relate to concept generation in the engineering design process [42] and were again tasked with assigning each team member a new role during the class period. The control group did not view this video nor did it assign any roles. All students were provided with information emphasizing the importance of innovation and creativity in the design process. Teams then completed an idea generation activity, where all individual members of each team were asked to sketch as many ideas as possible in 15 minutes. Finally, all participants completed a psychological safety survey. The control group was given a survey asking about the effectiveness of the initial psychological safety video given at Time Point 1 and the team's level of psychological safety. The intervention group was given this survey, in addition to questions relating to the video presented at the beginning of class, the effectiveness of the lenses at improving psychological safety, and the usefulness of each of the intervention-lenses.

During ***Time Point 3***, teams followed a concept selection activity in which they reviewed all ideas generated during Time Point 2. The intervention group was shown another video about the lenses of psychological safety as they relate to concept selection in the engineering design process [43]. The control group did not view this video. The concept selection activity consisted of assessing the ideas created from Time Point 2 in a random order. Students individually categorized the ideas into "Consider" or "Do Not Consider" divisions, to separate ideas they thought would accomplish or not accomplish their problem statement. Teams chose four ideas to be focused on in the low-fidelity prototype state (Time Point 4). All participants completed a psychological safety survey. The control group was given a survey asking about the effectiveness of the initial psychological safety video given at Time Point 1 (which was given a few weeks ago, at this stage of the design process) and the team's level of psychological safety. The intervention group was given this survey, in addition to questions relating to the video presented at the beginning of class, the effectiveness of the lenses at improving psychological safety, and the usefulness of each of the intervention-lenses.

During ***Time Point 4***, students were given a lecture on low-fidelity prototypes, and teams created prototypes based on the four chosen ideas from Time Point 3. The intervention group was shown its last video about the lenses of psychological safety aimed at completing the project in the engineering design process [44]. The control group did not view this video. To make the prototypes, students were given common household materials (e.g. Legos, cardboard, paper, etc.). Teams received feedback from their classmates on the effectiveness of their idea. As with Time Point 2 and Time Point 3, all participants completed a psychological safety survey. The control group was given a survey asking about the effectiveness of the initial psychological safety video given at Time Point 1 (which was given a few weeks ago, at this stage of the design process) and the team's level of psychological safety. The intervention group was given this survey, in addition to questions relating to the video presented at the beginning of class, the effectiveness of the lenses at improving psychological safety, and the usefulness of each of the intervention-lenses.

During ***Time Point 5***, teams completed the design project. The teams completed final deliverables including a final report, presentation of their final design project in PowerPoint, high-fidelity prototype, and CAD representation of their design. Finally, students completed their final psychological safety survey. The control and intervention groups completed the same survey presented at the end of Time Point 1. The purpose of the survey was to check the student's level of understanding of psychological safety and the factors that contribute and build psychological safety. The intervention group completed the same survey as the control group, in addition to four questions about the usefulness of each of the intervention-lenses.

Metrics

To answer our research questions, several metrics were computed. This section serves as a summary of these items.

Psychological Safety Knowledge Self-Efficacy Survey: The Psychological Safety Self-Efficacy survey was given at the beginning and end of TP1, and at the end of TP5. This survey consisted if six statements that asked participants to rank their knowledge of psychological safety on a 5-point Likert scale from 1 (completely disagree) to 5 (completely agree). Example statements included "I can describe to a peer what psychological safety is," and "I can describe to a peer the factors that contribute to improving psychological safety in teams". In addition, four open-ended questions were presented including, "When do you think psychological safety is most important in teamwork and why?" and "What are some specific steps that you can take to improve psychological safety in your team?". Survey responses to these open-ended items were rated by two raters in terms of their correctness from 0 to 3 (0 being did not answer question, 1 being incorrect answer, 2 being pieces of answer are correct and answer is incomplete, and 3 being the correct answer).

Perceived Psychological Safety: Psychological safety was captured five times at the end of TP1-TP5. Specifically, students were asked to "rate your team's psychological safety after

TABLE 1: SUMMARY OF RESULTS FOR RQ1

		F	*p*	*η2*
"I can describe to a peer what psychological safety is"	time x condition	*F(1.384, 48.423) = 1.868*	0.175	0.51
	time	***F(1.384, 48.423) = 82.338***	**0.001**	**0.702**
	condition	*F(1,35) = .310*	0.581	0.009
"I can describe to a peer why psychological safety is important"	time x condition	*F(1.384, 48.423) = 1.868*	0.175	0.051
	time	***F(1.573, 55.049)= 42.586***	**0.001**	**0.549**
	condition	*F(1, 35) = .283 .008*	0.598	0.008
"I can describe to a peer the factors that contribute to improving psychological safety in teams"	time x condition	*F(1.657, 57.988) = .383*	0.644	0.011
	time	***F(1.657, 57.988) = 58.846***	**0.001**	**0.627**
	condition	*F(1, 35) = .001*	0.972	0.001
"I can describe to a peer clear actions I can take to help build psychological safety in a team"	time x condition	*F(2, 70) = .162*	0.851	0.005
	time	***F(2, 70) = 43.434***	**0.001**	**0.554**
	condition	*F(1, 35) = .006*	0.939	0.001
"I can identify when my team has high or low levels of psychological safety"	time x condition	*F(2, 70) = 1.396*	0.255	0.038
	time	***F(2, 70) = 34.136***	**0.001**	**0.494**
	condition	*F(1, 35) = .305*	0.585	0.009
"Building psychological safety in teams should only be considered at the start of a team project"	time x condition	*F(2, 70) = .682*	0.509	0.019
	time	*F(2, 70) = 2.633*	0.079	0.07
	condition	*F(1, 35) = .314*	0.579	0.009

today's activities?" on a scale from 1 (low psychological safety) to 5 (high psychological safety). This reduced survey scale was used to minimize the potential for survey fatigue. However, we also subsequently validated this approach in a follow up study where we collected the traditional 7-time survey by Edmonson [7], identifying an ICC(2) of 0.70 validating this approach.

The Lenses of Psychological Safety: At Time Points 1-5, each participant in the intervention groups completed a survey that asked them, "To what extent did your team use each of these lenses today in class (TP2-4)/ throughout the project (TP5)?". The participants were provided with the four lenses and a Likert scale from 1 (not at all) to 5 (extensively). They were also asked to denote (through an open text box) which lens they thought was most and least useful, and why.

RESULTS AND DISCUSSION

This section displays the results of this study with reference to our research questions. SPSS v.28 was used to conduct the statistical analysis and a value of $p < .05$ was used to determine statistical significance [45]. Results are presented as Mean ± Standard Error unless otherwise denoted.

RQ1: What impact does the frequency of videos and role assignments have on Psychological Safety Self-Efficacy?

The goal of our first research question was to identify the impact of video frequency and the use of assigned roles on student *Psychological Safety Self-Efficacy and Knowledge*. As a reminder, this assessment was provided at the start of the intervention (TP1), at the end of TP1, and at the end of the project (TP5). We hypothesized that students in the intervention group who received additional videos and information on the lenses would have higher ratings of psychological safety self-efficacy compared to students in the control group [28, 32]. We also expected that the intervention group would have a higher retention of Psychological Safety Self-Efficacy at the end of the project because they received reinforcements and practice attempts through the use of the lenses [23, 24].

To investigate this question, a Repeated Measure ANOVA was computed. Specifically, the between-subjects factor was the intervention condition (intervention or control), and the within-subjects factors were the time points (pre-TP1, post-TP1, and TP5). Student responses to each of the 6 questions of the *Psychological Safety Self-Efficacy and Knowledge* were analyzed. Prior to running our analysis, assumptions were checked. The results showed that there was homogeneity of variances ($p > .05$) and covariances ($p > .001$), as assessed by Levene's test of homogeneity of variances and Box's M test, respectively. Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(2) = 7.892, p = .019$, therefore we used the Greenhouse-Geisser correction. In addition, while Shapiro-Wilk's test of normality revealed that the data was not normally distributed ($p < .05$), the analysis continued due to the fact that the repeated measure ANOVA is robust to deviations from normality [46]. Once assumptions were checked, the results were computed.

The results of the ANOVA failed to reveal a significant interaction effect between Time and condition (intervention/ control), for any of the six questions (p > .127), see Table 1 for summary of results. In addition, the main effect of the intervention on self-efficacy was not statistically significant, *p > 0.579).* However, the simple main effect of time, was significant for questions 1-5 (p < 0.001). Specifically, the results showed that there was a statistically significant increase from pre-TP1 to post-TP1 and Pre-TP1 and TP5, but there was no difference between post-TP1 and TP5, see Figure 2 for Means and SE.

These results refute our hypothesis as we expected there would be a statistical significance between the conditions for self-efficacy over time. Due to the reinforcements and frequency

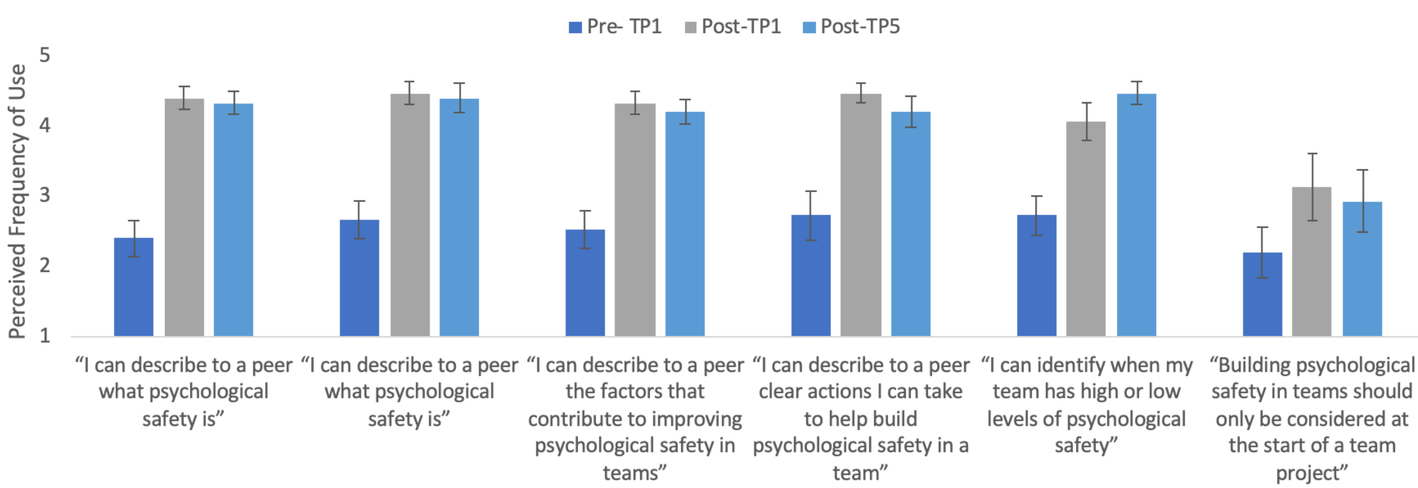

Figure 2: MEAN AND STANDARD ERROR BAR CHART OF SELF-EFFICACY FOR THE SIGNIFICANT MAIN EFFECT OF TIME ON PSYCHOLOGICAL SAFETY SELF EFFICACY. THERE WAS NO SIGNIFICANT INTERACTION EFFECT FOR CONTROL/ INTERVENTION CONDITION.

of use of the lenses in the intervention condition [23, 24]. The results do show that the initial video improved psychological safety self-efficacy based on a comparison between the baseline survey results to results at later testing points for both the intervention and non-intervention groups [28]. Additional testing could further confirm this point, as stated in the conclusion.

RQ2: Was there a difference in a perceived psychological safety between the intervention and non-intervention groups for throughout the design process?

While RQ1 focused on the impact of the intervention on self-efficacy gains, RQ2 turned to focus on the impact in perceptions of team psychological safety. We hypothesized that the groups given the interventions would have a higher perceived psychological safety over the five time periods because team roles can help team members develop creative ideas, postpone judgment [29], and effectively resolve conflict [31]. These factors correspond with team members feeling comfortable sharing their ideas, which should improve team performance and psychological safety as a result [8]. In order to answer this research question, the *Perceived Psychological Safety* survey responses from TP1-5 were analyzed and compared between groups using a two-way mixed ANOVA. The between-subjects factor was the intervention condition (intervention or non-intervention), and the within-subjects factors were the time points (TP1-TP5).

Prior to running the analysis, we checked several assumptions. First, there were outliers in the data, as assessed by inspection of a boxplot, however we kept these data points, as it they did not impact the conclusion of our results. The data was not normally distributed, as assessed by Shapiro-Wilk's test of normality ($p < .05$), except for non-intervention TP1 and non-intervention TP3. However, two-way ANOVAs are robust to deviations from normality [46]. There was homogeneity of variances ($p > .05$) and covariances ($p > .001$), as assessed by Levene's test of homogeneity of variances and Box's M test, respectively. Mauchly's test of sphericity indicated that the assumption of sphericity was met for the two-way interaction,

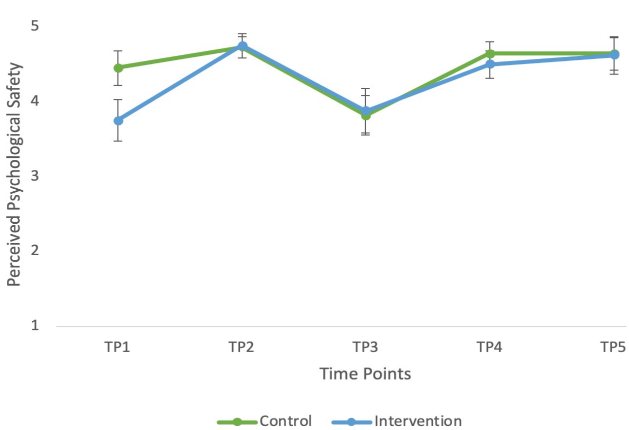

Figure 3: MEAN (AND ST. ERROR) OF PERCEIVED PSYCHOLOGICAL SAFETY IN THE CONTROL AND INTERVENTION GROUPS OVER TIME

$\chi^2(2) = 10.339$, $p = .326$, meaning the statistical result will not be biased.

The results showed that there was no statistically significant interaction between the condition and time on Perceived Psychological Safety, $F(4, 68) = 1.150$, $p = .341$, partial $\eta 2 = .063$, see Figure 3. However, the main effect of time showed a statistically significant difference in mean psychological safety levels at the different time points, $F(4, 68) = 6.777$, $p < .001$, partial $\eta 2 = .285$. Specifically, TP3 ($3.840 \pm .834$) had a significantly lower perceived psychological safety than TP2 ($4.73 \pm .452$), TP4 ($4.58 \pm .507$), and TP5 ($4.63 \pm .684$). There were no other significant differences.

These results refute the hypothesis in the sense that the intervention group did not consistently have higher perceived psychological safety. The intervention group started with a higher perceived psychological safety, but the intervention and non-intervention groups equalized at TP2. The length of time a team interacts was shown to be a factor in improving psychological safety, which could explain these results [18]. The relationship of a decreased level of psychological safety at TP3 correlates with a study by completed by Cole et al. [19] who found that psychological safety during the concept generation process (TP3) was not significantly related, and psychological safety did not influence the number of generated ideas.

RQ3: Did the perceived utility of the lenses change throughout the design process?

The objective of the third research question was to discover the utility of the four lenses at each time point by analyzing the Lenses of Psychological Safety Survey. Specifically, our hypothesis was that students would perceive the utility of the video interventions to be increasingly beneficial because information would be repeated over time [23, 24]. To investigate this question, we ran a repeated measure ANOVA. The within-subject factors were the specific lenses at the time points.

In order to answer this question, a one-way repeated measure ANOVA was conducted to determine whether there was a statistically significant difference in perceived utility of the videos over the four time periods in which videos were shown (TP1-TP4). There were no outliers in the data and the data was normally distributed at each time point, as assessed by boxplot and Shapiro-Wilk test ($p > 0.05$), respectively. The test of sphericity was met, as assessed by Mauchley's test of sphericity $\chi^2(4) = 5.933$, $p = .314$. The effect of time did elicit statistically significant changes in the perceived utility of the videos, $F(3) = 7.791$, $p < .001$, partial $\eta 2 = 0.327$. Post-hoc analyses with Bonferroni adjustments revealed that the perceived utility of the videos was statistically significantly higher at TP1 ($4.29 \pm .187$) and TP2 ($4.118 \pm .208$) than at TP3 ($3.059 \pm .290$). In addition, TP1 ($4.29 \pm .187$) was significantly higher than TP4 ($3.588 \pm .272$).

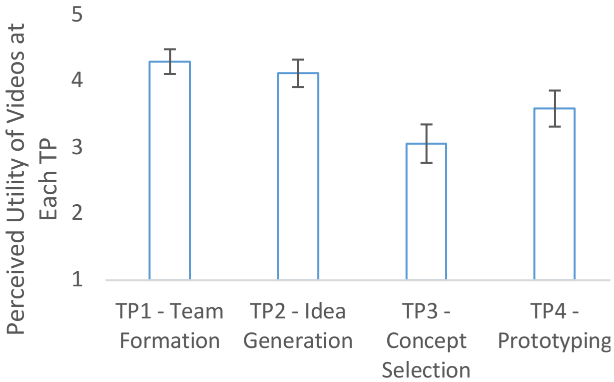

Figure 4: MEAN UTILITY OF VIDEOS AT EACH TIME POINT.

These results refute our hypothesis. While prior work has shown repeated video attempts can be beneficial [23, 24], as seen in Figure 4, the video interventions did not become increasingly beneficial over time. Students perceived the video interventions to be most useful at TP1 and least useful at TP3. Psychological safety during the concept generation design phase is not significantly related [19], and it is possible that since psychological safety develops over time, the lenses are not needed as often at later points in the design process [18].

RQ4: What was the perceived usefulness of the Lenses of Psychological Safety throughout the design process?

The final research question was developed to determine the utility of the repeated videos in the intervention condition. Our hypothesis was that given what the lenses can provide to a team, they would be most useful at certain time points of the design process (team formation, idea generation, concept selection, prototyping, and end of project [19, 36]). We hypothesized the Turn-Taking Equalizer and Point of View Shifter to be most useful during concept selection; Creativity Promotor to be most useful during idea generation, and Affirmation Advocate to be most useful throughout the whole project.

Prior to running the analysis, we checked several assumptions. First, as assessed by inspection of a boxplot, Turn-Taking Equalizer and Point of View Shifter had no outliers in the data, but Affirmation Advocate and Creativity Promoter had outliers. We conducted the analysis with and without the outliers and found they had no impact on the significance of the results. As such, we left the outliers in the data. Mauchly's test of sphericity indicated that the assumption of sphericity was met for all lenses (Turn-Taking Equalizer: $\chi^2(2) = 6.538, p = .693$; Affirmation Advocate: $\chi^2(2) = 6.764, p = .670$; Point of View Shifter: $\chi^2(2) = 6.856, p = .662$; and Creativity Promoter: $\chi^2(2) = 11.413, p = .260$).

Once assumptions were checked, an analysis was conducted. The results failed to show a show a statistically significant difference in the main effect of time during the design process for Turn-Taking Equalizer: $F(4, 36) = .298, p = .877$, partial $\eta^2 = .032$, Affirmation Advocate: $F(4, 36) = .351$, $p = .842$, partial $\eta^2 = .037$; Point of View Shifter: $F(4, 36) = .314, p = .867$, partial $\eta^2 = .034$; or Creativity Promoter: $F(4, 36) = .203$, $p = .935$, partial $\eta^2 = .022$. These results indicate that the lenses were equally useful throughout the design project, see Figure 4.

These results refute our hypothesis. While it was expected the benefits of the lenses would complement stages of the design process, this did not occur. As seen in Figure 5, the lenses stayed at about the same extent of use, with Affirmation Advocate used slightly more often compared to the other lenses.

CONCLUSION

The goal of this study was to determine the relationship of video interventions to level of psychological safety self-efficacy and participant psychological safety levels, and to understand the

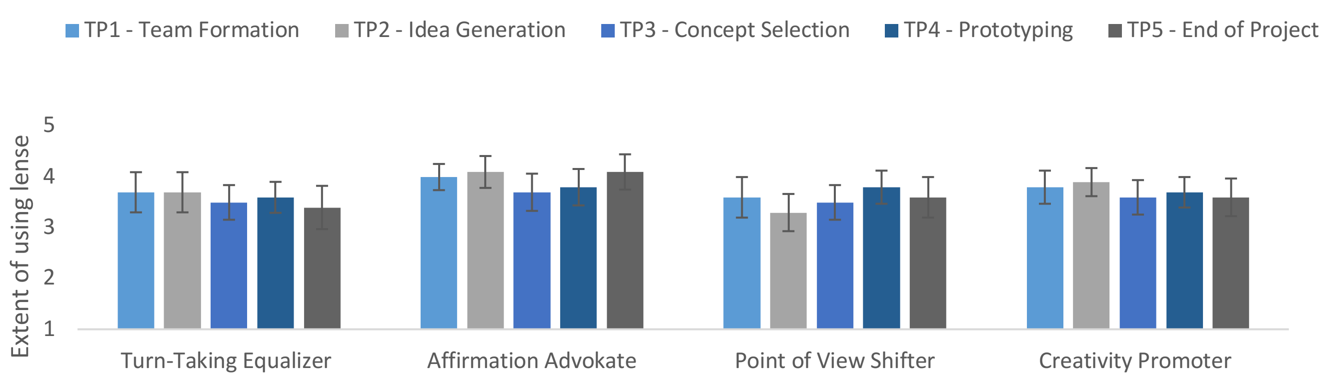

Figure 5: MEAN AND STANDARD ERROR BAR CHART OF EXTENT OF USE RATING OVER TIME POINTS TP1-TP5

usefulness of video interventions from a student point of view in general and throughout the engineering design process over time. The main findings from this study were as follows:

1. A video shown at the beginning of project work educating the student on psychological safety was effective in improving psychological safety self-efficacy. Repeated videos did not improve this affect.
2. There were no differences in the perceived psychological safety of the team between the intervention and control conditions across time points.
3. The results indicated that a reduced number of videos may achieve the same effects, particularly with the removal of the video in TP3.
4. The students reported using the lenses frequently throughout the design process.

The results from this study help to answer preliminary questions concerning the relationship between psychological safety and the use of the four lenses of psychological safety in engineering teams. Significantly, an initial video intervention educating all participants on psychological safety increased psychological safety in the engineering teams over all time periods. Furthermore, the intervention group's initially higher psychological safety indicates that the group's supplemental first video increased the team's level of psychological safety. This demonstrates that controlled interventions can impact and improve psychological safety with engineering teams.

However, additional video interventions with lenses showed no statistical improvement in psychological safety when intervention groups were compared to non-intervention groups. At the same time, participants who received the interventions with lenses and were encouraged to use the four lenses perceived increased psychological safety in their groups even though a statistical analysis did not show this relationship (see Figure 3).

This study is important because it exposes the importance of a controlled intervention on psychological safety in engineering teams while raising the tantalizing question of what type of controlled intervention would have the greatest impact. While the video interventions in this study did not statistically improve psychological safety in the teams studied, additional research is needed to determine whether in person (compared to video) interventions would be more effective, especially if those in person interventions were followed up with monitoring of the use of the four lenses.

In addition, the inconsistency between the participants' view that use of the lenses increased psychological safety and the statistical analysis showing no such relationship suggests that psychological safety may have been increased in the intervention groups without being adequately measured. Additional research could analyze different methods of measuring psychological safety. For example, individual contributions could be counted or team performance could be numerically graded and compared between intervention and non-intervention groups. The use of a Likert scale in this research is another limitation. Students were asked to, for example, quantify their team's psychological safety. It may not possible to understand true opinions numerically.

Further work also needs to be completed on a larger sample size. This study was completed with only 16 teams of 54 people, separated between the non-intervention and intervention groups. A larger sample population is needed to confirm these findings. Future work should include more effective verification with the students to ensure that they paid attention to the videos and maintained use of assigned roles. Open-ended questions were asked and analyzed separately as one form of quality-check, but an easier form should be developed. The finding from RQ1, and main finding #1, could be strengthened by conducting a further study that includes a third group of subjects who are not given a video and are tested at each of the time points. In addition, the participants were college-aged individuals and it is possible these results may be different for those who are professional engineers already in the workplace.

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