Psychological Safety in Undergraduate Engineering Teams

Dr. Michelle Marincel Payne, Rose-Hulman Institute of Technology

Dr. Michelle Marincel Payne is an Associate Professor in the Civil and Environmental Engineering at Rose-Hulman Institute of Technology. She earned her Ph.D. in Environmental Engineering from the University of Illinois at Urbana-Champaign, her M.S. in Environmental Engineering from Missouri University of Science and Technology, and her B.S. in Nuclear Engineering from the University of Missouri-Rolla (same school, different name). At Rose-Hulman, Michelle is co-leading a project to infuse an entrepreneurial-mindset in undergraduate students' learning, and a project to improve teaming by teaching psychological safety in engineering education curricula. Michelle also mentors undergraduate researchers to investigate the removal of stormwater pollutants in engineered wetlands. Michelle was a 2018 ExCEEd Fellow, and was recognized as the 2019 ASCE Daniel V. Terrell Awardee.

Dr. Kenneth W Lamb P.E., California State Polytechnic University, Pomona

Kenneth is a Professor of Civil Engineering at Cal Poly Pomona and a licensed Professional Engineer in Nevada with experience working on a variety of water, stormwater, and wastewater system projects. He also oversees the College of Engineering Leadership Program at Cal Poly Pomona.

Mr. Seth Claberon Sullivan, Texas A&M University

Seth Sullivan is the Director of the Zachry Leadership Program in the College of Engineering at Texas A&M University. Prior to joining the university, he worked in consulting in the private sector and as an analyst in the U.S. Government. Heâ€™s earned

Psychological Safety in Undergraduate Engineering Teams

Abstract

Psychological safety is increasingly recognized as a critical factor in the success of teams. High levels of psychological safety have been linked to improved performance, creativity, and individual well-being within teams. In engineering education, teaming is both a pedagogical best practice and a required learning outcome. Despite its significance, psychological safety remains underexplored in engineering education, especially in terms of actionable teaching strategies. This paper builds on a previous work and highlights psychological safety as a valuable assessment tool for evaluating team dynamics. Additionally, building on previous work, this paper measures the impact of psychological safety interventions from multiple programs. Drawing connections to established models such as an affective domain psychological safety framework and applying team role awareness and interpersonal curiosity to engineering teams, we identify promising interventions from experience and the literature and share their impact.

Introduction

Dr. Amy Edmonson's work to create and define learning organizations has begun to permeate some areas of work, especially in the business realm [1]. A learning organization is a classification of team function where everybody is working and learning and disclosing all facts to help the team learn and improve from small risks that were taken [2]. Edmondson's research found that certain teams within the same hospital produced different patient outcomes, and after closer review, she observed that teams that became learning organizations did seven things positively. From the seven items she created a survey that a team could use to guide a reflection on where they are in their growth towards becoming a learning organization.

The seven survey items that Edmonson created are related to fostering psychological safety in teams and are included in the appendix of this paper. They can be summarized into the following categories of scenarios commonly encountered in teams: (1) making mistakes, (2) asking for help, (3) taking small risks, (4) discussing tough issues, (5) respecting the contribution of others, (6) helping members feel like they belong, and (7) supporting each other in team tasks. Teams that achieve positive outcomes in each of these areas actively create what Edmonson coined, "psychological safety" in a team. While not the only tool, psychological safety is critical to creating high-performing teams and, in turn, achieving team and individual goals.

Leaders can support the fostering of psychological safety on their teams in several different ways. Nguyen et al. found that when leaders build strong relationships with employees, feelings of psychological safety increase and turnover decreases [3]. Edmonson also notes that a leader

who demonstrates a learning mindset when working on challenging problems with their teams also promotes psychological safety in their teams [1].

With these thoughts in mind, we began to be curious about the state of psychological safety and student engineering teams. This work in progress builds upon two pilot studies presented previously and expanded to include data from additional universities [4,5] and our previous combined study of four engineering programs [6]. In this update, we present data to demonstrate whether measures we are continuing or adding are helping students learn to foster psychologically safe team environments. Each of the universities participating in this study provides leadership or team development training to students in some way. In this study, our specific research questions are:

> [Q1] How are undergraduate engineering students experiencing psychological safety in their project teams?
>
> [Q2] Do students who receive training or instruction in psychological safety experiencing greater levels in their teams than do students who do not receive the training or instruction?
>
> [Q3] What best practices might exist for fostering psychological safety in these teams?

Approaches at Each Institution

The current study builds on previous work [4, 5, 6] done across four diverse universities—Rose-Hulman Institute of Technology, James Madison University, Cal Poly Pomona, and Texas A&M—to assess levels of psychological safety in undergraduate engineering student teams. The four institutions selected represent different sizes of engineering programs as well as different student body compositions which may impact the level of psychological safety in teams. Rose-Hulman Institute of Technology (RHIT) and James Madison University are relatively small engineering programs that are predominantly white with engineering student populations of approximately 1,650 and 670 respectively. Cal Poly Pomona (CPP) is a Hispanic-serving institution with a large minority population of Asian Pacific Islander students where the engineering program has 6,000 undergraduate students. Texas A&M University (A&M) has 19,000 undergraduate engineering students from a variety of backgrounds. As a result of these differences in type, size, and makeup of the universities, there were differences in the approaches used to encourage the fostering of psychological safety on teams across our programs. Some of these approaches were more hands-on while some were more observational.

This study focuses on Rose-Hulman's and Cal Poly Pomona’s continued measurement of team psychological safety; we were unable to collect new data from James Madison or Texas A&M. Updates in efforts to teach psychological safety at the two institutions that have continued to measure psychological safety are highlighted below.

At Rose-Hulman, interventions exist in the civil and environmental engineering curriculum. Since last reported [5,6], a few reinforcement touchpoints were added in the civil and environmental engineering curriculum. Through a refresher module, students were reminded of the three psychological safety attitudes introduced in their Introduction to Design course in freshman year. These attitudes are that [5]:

1. Every Idea Has the Potential to Contribute to a Positive Outcome,
2. Questioning an Idea Can Provide Valuable Insight,
3. Applying the Brake Can Be Productive.

While these attitudes were taught and practiced in EM103 – Introduction to Design, to reinforce and emphasize the importance of these attitudes, they were shared with students again at significant teaming opportunities in the curriculum:

- Sophomore year: EM202 – Mechanics of Materials
- Junior year: CE471 – Water Resources Engineering
- Senior year: CE486 – Technical Synthesis and Design (capstone design)

Materials about the three attitudes were shared and reintroduced when students were entering teaming experiences in the respective courses. In the sophomore and junior years, students did not perform any in-class exercises or activities designed to explicitly practice these attitudes but they did reflect on questions related to the attitudes. However, in capstone design, students practiced attitude 2 in the fall term of the full-year capstone design experience through the same role-playing exercises taught during their Introduction to Design course in freshman year. The activities associated with teaching these attitudes are described in detail as previously reported [5].

At Cal Poly, interventions exist at the college level and at the department level. Specific efforts are described in [6]. As a quick reference here, the Aerospace department as well as the industrial and Manufacturing departments provide intentional leadership and teaming interventions within their programs. Since completing the benchmarking study in 2024, the Electro-Mechanical and Systems Engineering Technology department implemented a program where students enrolled in their first semester of their capstone experience receive training on Strengths-based teamwork and conflict resolution, Team Role framework (after Belbin [7]), and the Arbinger Institute's Outward mindset [8]. Finally, at the college level, the engineering leadership program provides workshops for all engineering students. Since the main assessment point is at the end of the senior capstone course, it is possible that some students completing their senior capstone may have been introduced to leadership lessons.

Methodology

To measure psychological safety, we continued to use the seven-item survey created by Edmondson [9] which uses a 7-point Likert scale to rate agreement with each item. Survey questions Q1, Q3, and Q5 are negatively worded and the responses were reverse-coded

(designated with an R below) such that a value of 1 was converted into values of 7, a value of 2 was converted into a value of 6, and so forth. Using positive and negative statements was intentional to ensure that participants read through each question and made intentional survey answer choices. The survey items include the following:

1. If you make a mistake on this team, it is never held against you. (R)
2. Members of this team can bring up problems and tough issues.
3. People on this team never reject others for being different. (R)
4. It is safe to take a risk on this team.
5. It is easy to ask other members of this team for help. (R)
6. No one on this team would deliberately act in a way that undermines my efforts.
7. Working with members of this team, my unique skills and talents are valued and utilized.

We wanted to be able to continue to help programs make informed decisions based on the survey results. To achieve this desire to support programs, we decided that a grade percentage would better convey the meaning of the results than simple number reporting so that programs could benchmark where they fall within the commonly used "grade" percentage approach academics are familiar with. We converted the survey responses into percentages to establish a single numerical value from each survey response between 0 and 1 and then converted these values into letter grades based on typical letter grade break points. For example, a student who responded to the psychological safety questions with a Likert score of seven (on the 7-point Likert scale) to six survey questions, and a Likert score of six to one survey question, received a "score" of 34 out of 35 possible points. As a percentage, this is computed as 0.97 or 97%. We assigned "grades" of A, B, C, D, or F based on the traditional break lines ($A \geq 90$, $80 \leq B < 90$, $70 \leq C < 80$, $60 \leq D < 70$, and $F < 60$). So, for our example, the student scored their team's psychological safety as an "A". With these results, we looked at the "grade distribution" as a way to enable programs to set goals for the percentages of A & B grades (i.e. > 80) versus C, D, and F (< 80) they may find desirable.

In addition to analyzing each survey response, we also analyzed the data resulting from each question individually. The question analysis included a comparing each question's score with the benchmark of 80, and also comparing the intervention versus control scores within each university. We make statistical comparisons using the parametric, two-tailed, student t-test assuming unequal variance. This approach is described by Adler & Roessler [10] and was used on the one-sample tests. For the two-sample t-test this was implemented using the T.TEST function in Excel.

Benchmark Results & Comparison Between Programs

Previously, we found the programs were achieving, for the most part, "B" and "C" grades (Table 1) with a mean of 80.4 and a standard deviation of 14.1 when summarizing the psychological safety data across both participating universities [6].

Table 1. Summary of psychological safety data from each university

University	*N*	Mean	Median	Std Dev
RHIT	133	82.3	85.7	13.3
CPP	190	78.3	80.0	14.4
Overall	369	80.4	82.9	14.1

Using updated data, we can update the benchmark data (Table 2). In this data, we also share the responses based upon whether they are a control sample or an intervention sample. The reported probabilities are from the t-test and the shaded cells denote significance where $p < 0.05$.

Table 2 shows that the overall psychological safety grades at Rose-Hulman were significantly greater than at Cal Poly Pomona and that the intervention groups at both universities achieved significantly higher psychological safety scores than the control groups. With this data we can demonstrate how students are experiencing psychological safety—students experienced it on their project teams at a "C+" to "B" level, addressing our first research question. The fact that intervention groups achieved significantly higher psychological safety scores compared to control groups enabled us to additionally answer our second research question. Students who receive training or instruction experience greater levels of psychological safety in their teams than those who do not receive training.

Table 2. Summary of updated psychological safety data from each university including intervention and control cohort data (the probability values shown come from the t-test and values < 0.05 are shaded as statistically significant)

University	Mean	Median	Std Dev	N
RHIT	83.7	85.7	13.16	297
Intervention	84.3	85.7	15.07	166
Control	79.9	83.7	9.76	131
P	*0.003*			
CPP	78.1	79.6	14.2	474
Intervention	81.9	82.9	12.9	373
Control	77.1	79.6	14.4	101
P	*0.001*			
P (RHIT vs. CPP)	0.000			

Table 3 shows the distribution of letter grades within each institution and across both universities. The grade distribution reveals the common letter grade categories that each student self-reported as computed through the survey results. This data shows that overall, a letter grade

of B is the most common result, but that individual student responses are distributed across all letter grades, indicating opportunities for improvement across the board.

Table 3. Letter grade distribution across all the data at each institution

University	A	B	C	D	F
RHIT (N = 297)	67 (22.6%)	129 (43.4%)	57 (19.2%)	25 (8.4%)	19 (6.4%)
CPP (N = 474)	90 (19%)	142 (30%)	120 (25.3%)	72 (15.2%)	50 (10.5%)
Overall (N = 771)	157 (20.4%)	271 (35.1%)	177 (23%)	97 (12.6%)	69 (8.9%)

The results in Table 3 can be used to set institutional goals and measure progress in a continuous improvement program. As examples, institutions can set goals related to increasing overall "Team GPA", increasing the ratio of A and B grades to C, D, and F grades, or decreasing the number D and F grades, to name a few options. With a quantifiable target, programs can then undertake efforts to address problem areas and then reassess if the numbers improve as a result.

Table 4 compares the average score per survey item overall to help inform our institutions on where to invest our efforts. Table 4 computes the control v. intervention probability for each question on the row noted as "$P_{Control\ v.\ Intervention}$." We also computed the probability that the mean of a given question is similar to the benchmark mean of 80. These results are labeled with the row $P_{Q\ v.\ Overall\ Mean}$. For Rose-Hulman, the analysis shows that for each question that was significantly different from the mean of 80 (Q3, Q6, Q7), the question result was *higher* than the expected mean. For Cal Poly Pomona, we see that Q2, Q3, Q4, and Q6 are significantly different from the mean, but Q2, Q4, and Q6 are all significantly *lower* than the benchmark. For Q2, Q4, and Q6 (bringing up tough issues, safe to take risks, and undermining efforts of others), these data show where Cal Poly Pomona can start investing effort in interventions to improve overall psychological safety.

Table 4. Psychological safety scores reported by each survey question and each institution as well as the overall score for each question (the probability values shown come from the t-test and values < 0.05 are shaded as statistically significant)

University	Q1	Q2	Q3	Q4	Q5	Q6	Q7
RHIT	77.9	80.1	88.8	78.2	81.5	84.2	82.4
Control	74.4	77.1	86.1	75.3	80.3	86.1	79.9
Intervention	82.3	83.9	92.3	81.9	83.1	81.8	84.8
$P_{Control\ v.\ Intervention}$	*0.002*	*0.000*	*0.002*	*0.001*	*0.292*	*0.114*	*0.012*
$P_{Q\ v.\ Overall\ Mean}$	*0.107*	*0.924*	*0.000*	*0.076*	*0.246*	*0.001*	*0.014*
CPP	80.4	71.7	86.1	72.5	79.5	75.8	80.6
Control	79.9	69.6	85.6	71.9	78.9	74.1	79.4
Intervention	82.1	79.3	88.0	74.8	81.6	82.3	85.0
$P_{Control\ v.\ Intervention}$	*0.369*	*0.000*	*0.259*	*0.225*	*0.272*	*0.004*	*0.009*
$P_{Q\ v.\ Overall\ Mean}$	*0.686*	*0.000*	*0.000*	*0.000*	*0.610*	*0.002*	*0.564*

Table 4 also reveals scores at the individual question level. Students receiving psychological safety training or instruction report significant improvements in team psychological safety over control cohorts indicated by specific survey questions. These intervention and control cohorts are specific to each university and thus well-matched for making comparisons. While Rose-Hulman participants reported more questions with significant differences between the cohorts (five of the seven questions), it is notable that both universities found significant improvements for two statements:

- "Members of this team can bring up problems and tough issues." (Q2)
- "Working with members of this team, my unique skills and talents are valued and utilized." (Q7)

These statements are somewhat foundational for engaging with a team, and it is, therefore, perhaps concerning that the control cohorts report a "C" grade for these questions, underscoring the idea that an average "grade" of a "C" may not adequately describe team psychological safety even as it is used as a benchmark for setting program goals. In that goal setting process, in terms of identifying where to expend effort, the lowest scored question was Q4 (safe to take risks) indicating that additional training could focus on how to improve safe risk-taking on teams.

All questions post-intervention at Rose-Hulman had values at or above a the minimum "B" grade, or in other words, were above a score of 80. Interestingly, for Q6 (not deliberately acting to undermines efforts), the control group scored greater than the intervention group with a score of 86 v. 82. While both control and intervention scores were above the minimum desired threshold of a "B" grade or 80 to begin with, this inversion between the control and intervention groups stood out to us. Interestingly, Edmonson notes that lower psychological safety can be reported on teams that simply have more exposure and awareness of psychological safety [1]. In other words, more awareness can lead to reporting lower psychological safety. This phenomenon is also reported in the foundational work of Reason [11], who pointed out that well-developed organizations are better at spotting problems, and reporting them, than underdeveloped organizations. While the work of Reason is about general organizational safety, Montgomery et al. [12] also identified this measurement paradox when observing levels of psychological safety in healthcare. We are not sure if the Q6 results for Rose-Hulman are evidence of the same phenomenon. However, the fact that we saw intervention data get worse led us to be curious, but this observation will be the focus of future work in our long-term research goals.

To address our third research question, what best practices might exist for fostering psychological safety, we were curious if there was a best score for each school compared to itself which could then point towards best practices. We again homed in on Q6 (not deliberately acting to undermines efforts). As already noted, Rose-Hulman saw a decrease in the score for the intervention cohort compared to the control cohort. However, Cal Poly Pomona saw a significant increase in reported safety of the intervention group versus the cohort group. Cal Poly Pomona

students may have tried to act on intervention teachings. This is an area ripe for continued development.

We want to acknowledge that a program may feel that true psychological safety is achieved only when all seven questions are actively improving between control and intervention groups. And, in fact, Edmonson's assessment for psychological safety was developed to be evaluated at the macro level, such that the survey should be considered as a whole. We agree, however, we believe that seeing individual dips, or inversions between control and intervention cohorts, can act as a sensor. These types of findings may indicate that there are opportunities for improvement. Making any one of these question areas stronger contributes to overall increases in psychological safety on teams.

Conclusions

Previously, our data showed that the mean psychological safety score across all programs was 80.4 with a standard deviation of 14.1 [6]. We previously reported this level as an acceptable benchmark for potentially predicting psychological safety in engineering student teams. We postulated, based on our previous study, that if we invest effort in improving team psychological safety, then we can make positive differences in students' reports of team psychological safety. This updated data appears to support that theory. Both universities included in this update find significant increases in psychological safety scores for intervention cohorts compared with control group cohorts, which demonstrates the positive impact of psychological safety instruction and opportunities to practice fostering psychological safety. This observed increase inspires additional action as well: knowing the impact of teaching students to foster psychological safety, we seek to bring all student teams to a highly functioning level by teaching students to foster psychological safety.

In addition to showing that intervention groups had significantly higher levels of psychological safety than the control groups, the analysis method provides other universities a means of identifying areas for improvement as well as assists with setting program goals as part of a continuous improvement process surrounding teams. For example, both universities identified places where they are doing well, and places where they can invest effort to improve.

While we observed improvements at both institutions, we also observed that there is not just one approach that stands out as "the key" to improving the overall psychological safety score. The beauty in this observation is that there is room for a variety of approaches. It appears that if there are intentional approaches towards teaching students to foster psychological safety, there is positive impact that can be achieved. We owe it to our students, our professions, and ourselves, to continue to invest in this work.

Future Work

To continue this work in progress, future work is needed to elucidate the impact of specific interventions. This includes testing the impact of various interventions on team psychological safety, conducting student focus groups to understand differences between institution interventions, and verifying if the benchmark of "80" is sufficient to yield positive team experiences that support individuals and teams. We think these approaches will uncover interventions or best practices for educators wishing to embark on an intervention program.

Specifically, we are curious to further probe Q4 and Q6 and investigate the degree to which, compared to control group teams, lower psychological safety can be reported on teams that simply have more exposure and awareness of psychological safety. We will also continue to gather data and monitor reported levels of psychological safety.

Ultimately, we intend to investigate the effect of supporting psychological safety formation in student teams further to be able to produce a set of recommendations to be made available to other engineering programs who desire to achieve high "grades" on student teaming using psychological safety as a measure. We will continue to collect data to inform the psychological safety benchmark for all engineering teams. We hope that the updated benchmark provided here can provide an assessment goal for each program or campus as they build their continuous improvement programs.

References

[1] Edmondson, A. C. (2018). *The fearless organization*. John Wiley and Sons.

[2] Senge, P. M. (2006). The fifth discipline: The art and practice of the learning organization. Broadway Business.

[3] Nguyen, T. D., Pham, L. N. T., and Vo, A. H. K. (2023). Faculty Turnover Intention in Vietnamese Public Universities: The Impact of Leader-Member Exchange, Psychological Safety, and Job Embeddedness, *Public Organization Review*, doi: https://doi.org/10.1007/s11115-023-00745-x.

[4] Lamb, K., Gipson, K., and Sullivan S. (2023, June). Assessing levels of psychological safety and teamwork satisfaction in engineering senior capstone teams, Proceedings from the 2023 *ASEE Annual Conference and Exposition*.

[5] Marincel Payne, M. K. and Hanson, J. H. (2023). Teaching students skills to foster psychological safety in a team environment, Proceedings from the 2023 *ASEE Annual Conference and Exposition*, Paper ID 36716.

[6] Marincel Payne, M. K., Lamb, K., and Sullivan, S. (2024, June). Benchmarking a foundation for improving psychological safety in teams. Proceedings from the 2024 *ASEE Annual Conference & Exposition*.

[7] Belbin, M. R. (2011). Management teams: Why they succeed or fail. *Human Resource Management International Digest*, *19*(3).

[8] Arbinger Institute. (2016). *The outward mindset: Seeing beyond ourselves*. Berrett-Koehler Publishers.

[9] Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative science quarterly*, *44*(2), 350-383.

[10] Alder, H. L., and Roessler, E. B. (1968). *Introduction to probability and statistics*. W.H. Freeman Publishers.

[11] Reason, J. (2016). *Managing the risks of organizational accidents*. Routledge.

[12] Montgomery, A., Chalili, V., Lainidi, O., Mouratidis, C., Maliousis, I., Paitaridou, K., and Leary, A. (2025). Psychological safety and patient safety: A systematic and narrative review. *PLoS One*, *20*(4), e0322215.