Investigating Psychological Safety in a Flipped Engineering Course

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Abstract— **Psychological safety (PS) refers to the shared belief that a team environment is safe for taking interpersonal risks (i.e., it is ok to be wrong or assert new ideas). PS has been shown to improve the cohesiveness of co-workers and improve group problem solving in various situations. In the flipped classroom model of instruction students watch video lectures before coming to class, then participate in structured learning activies during class meeting times. In flipped classes that use small group or team based learning activities during class, which many do, students' level of PS, willing to ask questions, make mistakes, and address new ideas for a topic without fear of negative feedback from peers, might be an important factor in their experience of the flipped class. For this paper, we collected self-report data from students enrolled in a flipped section of Calculus III. Students were asked to answer validated survey questions about PS to assess their current level of PS at different times in the course. We used this data to assess students' PS at the beginning of a flipped class, and examine whether PS changes over the course of the semester in a flipped class. The results of this study will inform educators about how PS builds in the team environment within a flipped classroom of Calculus III. Additionally, the findings of this study may highlight ways that some of the disadvantages to PS in the flipped classroom can be addressed so that they are not a detriment to student success.**

Keywords— Psychological safety; teams; engineering

I. INTRODUCTION

Psychological safety (PS) is the shared belief that a group or team of people are a safe place for taking interpersonal risks (e.g., sharing new ideas, asking questions, etc.) and has been linked to better team outcomes [1]. Thinking about a team environment where PS appears to be high, the team is most likely productive and a good place to try new ideas with the group and a good situation for learning from mistakes. This would be the case because team members are free to make honest mistakes and ask genuine questions. In fact, environments with better PS are generally perceived as less judgmental and more conducive for learning [2-3]. PS can be contrasted with blamestorming, a team situation in which team members are assigning responsibility for a mistake or failure [4]. As such, PS could have applications in higher education, especially as it relates to problem-based or active learning classrooms.

Flipped learning classrooms are relatively new phenomena in higher education. Flipped classrooms involve reversing the traditional classroom lecture and problem-based homework paradigm that has been the stalwart setup in higher education courses [5]. In these new flipped classrooms, the lecture is moved to outside of class (usually in a video format) and work on various problems are moved to classroom time; allowing students more access to instructors while practicing what they learned in the video lecture [6]. Flipped classrooms often employ an active learning methodology to instruction, meaning that students are more engaged in the learning process [7]. Therefore, the flipped and active learning modalities of instruction involve classroom teamwork, sometimes refered to as learning pods [5,8]. Other flipped classroom activities draw on team based learning strategies. PS is likely an important factor for students participating in these types of learning activities.

PS has been linked to better work team performance, especially when there are intra-team conflicts [9]. Since the 1990's, PS has experienced a research renaissance; it began in business and organizations and is more recently, but less predominantly, being explored in the classroom [10-11]. Research on PS in education is still a relatively sparse. Thus far, most research has focused on PS as a requirement for better learning spaces [12], in tutor-student professional relationships [13], conversational learning (e.g., a seminar course) [14], and in virtual communities (e.g., an online course) [15].

Previous studies primarily focus on PS in terms of its interpersonal benefits, but have yet to really focus on educational outcomes (i.e., grades, learning team performance, class attendance, etc.). With there being such a vast amount of unexplored territory in educational PS, there could be more information to find about the construct's relationship to engineering education, and more broadly to higher education, specifically when learning activities use small group or team based collaborative learning. Given the lack of information on PS in the classroom, this study will hopefully serve as a start to the conversation on the importance of PS in educational settings, especially flipped/active learning classrooms

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The present study explores PS in a flipped classroom setting in an undergraduate-level mathematics course for engineering students. Data were collected during the first nine weeks of the semester, about every two weeks, starting with the second week of the course. This allowed the researchers to assess students initial PS and see if there were changes in PS as students participated in team learning during class meetings.

II. Method

This study was approved by the institution's Institutional Review Board (IRB), reference number 17.0350.

A. Participants

Participants in the study were students enrolled in two sections of CALC-III during the spring semester. A total of 73 students enrolled in the two sections. The CALC-III course was taught using the flipped classroom model of instruction [4,15]. A subset of the students were enrolled in the prerequisite course CALC-II the previous semester (n = 32) when it was also taught using the flipped classroom model of instruction.

B. Course Format

CALC-III is four credit hour class that met five days a week. Sections met for 50 minutes on Monday, Wednesday, and Friday, and both sections met together on Tuesdays and Thursdays for 75 minutes. The Monday, Wednesday, Friday classes met in an active learning classroom that seats 50 people. On Tuesday and Thursday, the classes met in a standard classroom (that had movable chairs), and exams were always administered on either Tuesday or Thursday.

The course was taught using the flipped classroom model of instruction [4,15]. The content of the course was divided into six units, with each unit composed of multiple lessons. Each lesson (or learning module) included multimedia content and practice exercises. The lessons were packaged and delivered using a web based, online, multi-media content system provide by the textbook publisher. Each lesson included links to an instructor created Microsoft OneNote notebook page with instructor created video lectures embedded in the page. In addition, each lesson also included a link to the appropriate section of the e-text book, any videos provided by the textbook publisher, and somewhere between one to three 'test your understanding" problems. Following the flipped classroom model, students were assigned a lesson to complete before coming to class.

In the flipped classroom model of instruction, class time is spent engaged in deeper learning activities. In CALC-III students worked collaboratively in teams on problems selected by the instructor. As a means to motivate students to prepare for and attend class, for each class meeting students were assigned a class activity score, the average of which contributed 10% to their final course average. The class activity score included an individual component and a team component.

After class, students worked on unit homework assignments and the lesson for the next class. There were six exams. Exams were completed with paper and pencils, excluding calculators, notes, or textbooks. There was a comprehensive pencil and paper final exam at the end of the semester.

Not all flipped class implementations use collaborative learning or team based learning, but the use of collaborative techniques is among the best pratices sited in the literature [21] on how to implement the flipped classroom model of instruction. In this course extensive collaborative learning, including team based learning was used during class, and this motivated the interest in examining students' PS.

Most class meetings began with a Readiness Assessment Test or RAT. The RAT was delivered using a recently developed online classroom response system [22] available as part of the textbook publisher's companion online multimedia package. This online system allowed the RATs to be scored automatically. It also supported team-based learning, where all the students complete the RAT individually first, then, in a second team round, they see each other's answers and answer the questions again, perhaps with a completely different answer. In the team round the team is immediately told if the submitted answer is incorrect, and the team can answer again, but with a scoring penalty. The system also allowed the final score for each RAT to be based in part on the individual score and part on the team score. For this class, the percentage was 70% individual and 30% team. The remainder of the class meeting time students worked with their team to solve more difficult problems related to that lesson or a previous lesson.

The design of these team based learning activities intended that students, after working independently to answer questions, would then discuss not only their answers but the thinking that lead them to make that choice, arguing why they thought their answer was correct. In many cases it was not expected that most students would know the answer to all questions on the RAT. The goal instead was to have students enage in discussion with their teammates, sharing their answers and their thinking. The literature on PS suggest that this is best achieved when students feel safe to be wrong, and at the same time feel safe to disagree and explore each others misconceptions. No effort was made to explicitly instruct students about PS. The instructor did spend considerable time on the first day of class explaining the flipped classroom model of instrunctions and the aspiration that students enhance their teamwork skills. The instructor also explained to students that the expectation was for them to come to class with questions and misunderstandings, and the sharing those with each other was part of the class. At this time the instructor did remind students to be respectful of others as they asked questions, or disagreed about answers to questions or solutions to problems.

C. Team Assignment and Peer Evaluations (PS)

On the first day of class students were asked to complete a survey, administered using CATME [17-20]. This survey asked the students a host of questions ranging from grade point average to hours a week they work off campus. Using the survey results and the Team Maker algorithm in CATME,

students were assigned to a team, with team sizes being either five or six students. The assignment to teams was made prior to the third-class meeting.

Students worked in these teams through the first exam, at which time the first peer evaluation survey was given, about two weeks into the course. At this time students were administered a peer evaluation survey using CATME. In the peer evaluation survey students were asked to rate the members of their team, including themselves, on how well they were: contributing to work, interacting with teammates, keeping the team on track, expecting quality, and having knowledge/skills. In addition, they were asked to report their team satisfaction and respond to seven psychological safety survey questions. The survey questions were part of CATME, but drawn from a validated scale [1]. Students were asked to respond to each prompt using a seven point Likert scale from very inaccurate to very accurate. The prompts are listed in table 1.

TABLE 1. PSYCOLOGICAL SURVEY PROMPTS [1].

1	If you make a mistake on this team, it is often held against you. *(scale reversed)*
2	Members of this team are able to bring up problems and tough issues.
3	People on this team sometimes reject others for being different. *(scale reversed)*
4	It is safe to take a risk on this team.
5	It is difficult to ask other members of this team for help. *(scale reversed)*
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.

A second peer evaluation was administered around the time of the second exam, about two weeks after the first peer evaluation. One item was added to the peer evaluation this time: how well does the team member ask follow-up questions. The overall evaluation also added a question on team conflict. The psychological safety questions remained the same. At this time, some adjustments were made to the teams. These adjustments reflected the fact that some students had dropped the course, some had never shown up, and still others showed very poor attendance during the first three weeks of the course. These team assignments stayed in force the rest of the semester.

A third peer evaluation was given about two weeks later, and a fourth was given about two weeks after that. No changes to the questions were made in either of these peer evaluations. There were a total of four times over the course of the semester that students filled out the PS survey. Students were told they would received a composite class activity score at the end of the semester that combined RAT scores and students' peer evaluations scores from CATME.

III. PRELIMINARY RESULTS

The reader should bear in mind that these results are preliminary in nature. The data reflects student responses and scores from approximately two-thirds of the semester. The additional data will be available at the end of the spring 2017 semester.

The additional data will allow for more detailed analyses and the inclusion of final course grade as an outcome variable.

Fig. 1 (on the next page) shows a histrogram of the PS scores from the first survey. The histogram shows the resulting PS scores by gender. Females (M = 6.32, SEM = .102) reported significantly higher PS than males (M = 5.89, SEM = .110). An independent samples t-test was conducted to determine if there was a statistically significant difference in PS scores for males and females and was statistically significant, $t(63) = -2.131$, $p < .05$. Levene's test for equality of variance was statistically significant, $F = 7.262$, $p < .01$. Because of the significant Levene's test result, the independent samples t-test results must be interpreted differently. After making adjustments based on the Levene's test result, there was still a statistically significant difference between males and females on their self-reported PS scores, $t(49.586) = -2.873$, $p < .01$.

The linear regression analysis was conducted to test the predictive ability of PS on course satisfaction. Exploratory analysis of the predictor variable, PS, found no violations of the assumptions of linear regression. The overall model was statistically significant ($F(1,64) = 30.894$, $p < .001$). PS significantly predicted course satisfaction (Beta = .574, $t(64) = 5.558$, $p < .001$).

A multiple linear regression analysis was conducted on the mean score of the first four exams, with PS, satisfaction, and conflict scores as the predictor variables. The satisfaction and conflict scores both violated the regression assumption of normality. Satisfaction scores were negatively skewed. To correct this, the scores were reflected and inverse transformed. Conflict scores were positively skewed. To correct this, the scores were square root transformed. The results of this analysis are reported using the transformed variable scores. The overall model was not statistically significant ($F(3,63) = 1.740$, $p = .169$, $R^2 = .08$). Satisfaction (Beta = -.305, $t(63) = -1.719$, $p = .091$) and conflict (Beta = -.045, $t(63) = -.338$, $p = .736$) were not significant predictors in the model. PS (Beta = .382, $t(63) = 2.268$, $p < .05$) was a statistically significant predictor of mean exam scores. There was, however, a significant negative bivariate correlation between satisfaction and conflict scores, $r(64) = -.289$, $p < .05$.

A 2 (male vs. female) by 2 (students who had a flipped version of the prerequisite course the previous semester vs. those who did not) between-subjects factorial ANOVA was conducted on PS and was not statistically significant, $F(3,64) = 1.529$, $p = .216$. Despite the lack of overall significance, the model detected a main effect for gender, such that females ($M = 6.372$, $SEM = .184$) reported higher PS than males ($M = 5.893$, $SEM = .102$). No other main effects or interactions were present in this model.

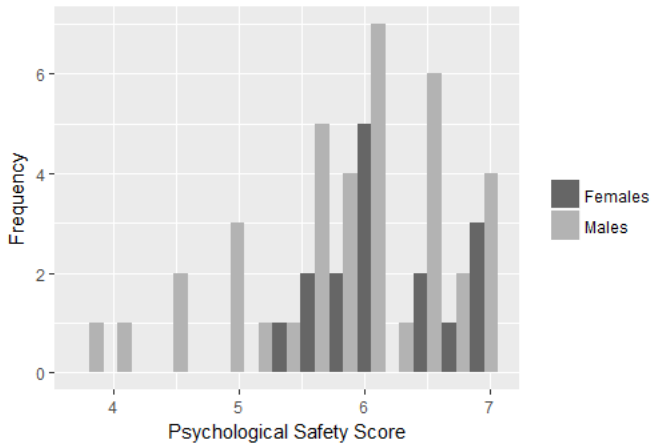

Fig. 1. Distribution of students' PS on first survey.

IV. DISCUSSION AND CONCLUSIONS

PS has been shown in the literature as being a significant factor in student success within team environments. This research attempts to quantify PS during a flipped Calculus III course. The difference in PS scores between males and females has potential implications for flipped classes given that there was some indication in the prelimary analysis that PS approached significance in predicting exam scores. It should be kept in mind that the difference between the number of males and females and the overall small number of students in this analysis indicates more analsyis is needed to determine if such a diffrenence acuatlly exists.

PS was shown to be a significant predictor for course satisfaction and it approach signifance for mean exam grades, but was not determined to be significant for satisfaction and conflict within the team. Futher exploration of PS as a predictor of mean exam scores may be the start of understanding the relationship of PS in team learning.

This prelimary analysis indicates that further research is needed to investage how PS relates to use of the flipped classroom model of instruction when group or team based activies are a predominant class activity.

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