Documenting Engineering Students' Counterproductive Teamwork Behaviors through Peer Evaluation

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Teamwork and the challenges of teaching it

Teamwork positively influences many learning outcome, yet to realize these positive outcomes, instructors should use appropriate strategies to make students' teamwork effective (Felder & Brent, 2001; Oakley, Felder, Brent, & Elhajj, 2004). Through productive collaboration in teams, students can create a common identity and gain positive attitude (Johnson, Johnson, & Smith, 2007), improve their social skills (Abrami et al., 1994; Shimazoe & Aldrich, 2010), and increase their critical thinking skills (Shimazoe & Aldrich, 2010; Windschitl, 1999).

Besides teamwork's many advantages for engineering students' learning, engineers need teamwork skills in the workplace, so team activities should prepare engineering students for industry (Heywood, 2016). Working in multidisciplinary teams is specified as an essential competency for engineering students at U.S. and Australia (ABET, 2019; Engineers Australia, 2013). Alumni of a large public university in U.S. rated the teamwork skill as the most important ABET competency for workplace (Passow, 2012). Engineers should be able to work in diverse teams, collaborate with people with different personalities, make decisions, bring their ideas in brainstorming sessions (Martin, Maytham, Case, & Fraser, 2005), and communicate effectively with team members (Darling & Dannels, 2003). So, it is very important to teach teamwork skills to engineering students.

Teaching students teamwork skills is hindered by the tendency for engineering students and faculty to be immersed in a culture focused more on technical issues rather than organizational behaviours (Ford, Voyer, & Wilkinson, 2000). Student misconceptions about the nature of engineering work and collaboration complicate this still further. Trevelyan (2014) listed some engineering misconceptions about collaboration. He stated that students and new engineers believe that communication skills are unimportant, that teamwork cannot be taught by instructors, and their boss is responsible for telling them what to do. New engineers favor working individually and exclude low-skilled team members from team activities (Dryburgh, 1999; Ford et al., 2000; Leonardi, Jackson, & Diwan, 2009). These beliefs and misconceptions make engineering organization managers' jobs more difficult because they lead to counterproductive practices, and managers have to not only teach appropriate practices to new engineers but also remediate any counterproductive practices (Leonardi et al., 2009).

It is best to correct any practices counterproductive to teamwork in the first-year of study because it is more challenging to correct them in following years (Leonardi et al., 2009). Yet to correct counterproductive practices, we must be able to identify them. Although a variety of counterproductive practices related to teamwork have been identified, for the purpose of this study we investigated two research questions:

- To what extent do engineering students marginalize students perceived to have lower skills?
- To what extent do students' (1) effort and (2) ability to interact with teammates (as assed by teammates) predict the relationship of their self-ratings of teamwork to ratings by peers?

The first research question measures whether engineering teams provide unequal opportunities for team members to learn. Since this study cannot determine causality, a relationship in the second research question might mean that overconfident students are more likely to disengage from their team and teammates, or could otherwise indicate that students who are less engaged with their team and teammates are less able and/or willing to evaluate their contributions properly.

Theoretical Framework

We draw our theoretical framework from Leonardi et al. (2009) and Kruger and Dunning (1999). Kruger and Dunning (1999) showed that a particular skill and the ability to accurately evaluate that skill are related. In the arena of teamwork, this would lead students with lower teamwork-related skills to be likely to overestimate their skills. Leonardi et al.(2009) documented various student misconceptions about engineering practice and how those misconceptions worsen with increasing time in their degree program. Leonardi et al. (2009) studied new engineering students and documented eight counterproductive work practices, including four work practices relate particularly to teamwork. Based on these counterproductive practices; students believe that engineers should (1) complete work alone, (2) ensure their contributions stand out, (3) rank themselves against others, and (4) exclude team members who are technically inferior. Students believe that success is measured by individual accomplishment. This norm acts as a guide to these counterproductive practices and resist instructors' attempts change their practices. The more students repeat the cycle of enactment and externalization, more they accept that these counterproductive practices are the proper work practices. In addition, based on the Kruger and Dunning (1999)'s study, students' lack of knowledge of engineering practice makes it more difficult for students to recognize their mistakes. Figure 1 summarizes our synthesized theoretical framework.

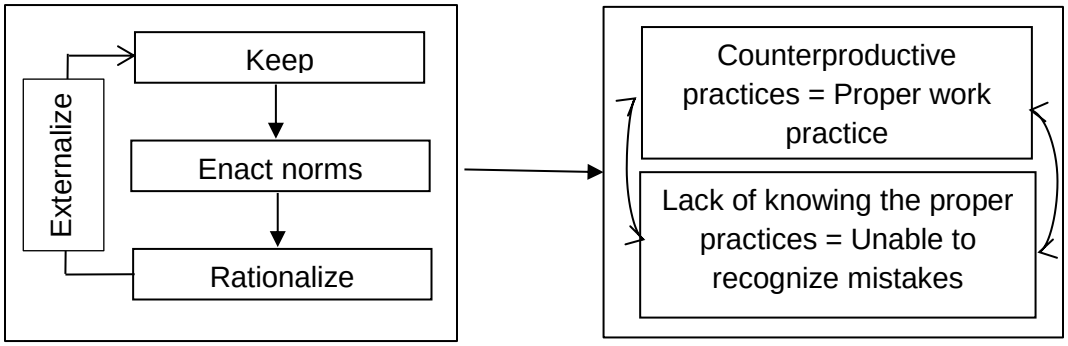

Figure 1: Theoretical framework

Methods

For both research questions, we used linear regression analysis. In the first research question, we used multiple linear regression to explore possible indicators of marginalization. For the second question, we conducted two simple linear regressions to measure how much students' (1) effort and (2) ability to interact with teammates (assed by teammates) predict the relationship of their self-ratings of teamwork to ratings by teammates.

Study Participants

Participants were from a first-year engineering course in Spring 2018 at a large institution in the Midwestern United States. Self-evaluation and peer evaluation data were collected near the end of a 16-week term that was also the end of an 8-week project. Data were

collected from 1545 students, but data from 120 students were excluded because they did not fully complete the surveys. A summary of participants' demographics is presented in Table 1.

Table 1: Demographic description of study participants

Factor		Number	Percent (%)
Gender			
	Female	376	26.4
	Male	1039	72.9
	Other or Prefer not to answer	10	0.7
Race/ethnicity			
	Asian	260	18.3
	Black	30	2.1
	Hispanic	151	10.6
	Native	3	0.2
	White	892	62.6
	Other	50	3.5
	Declined to answer	39	2.7
International student?			
	Yes	207	14.5
	No	1218	85.5

Data/Variables

Data were collected using CATME (Comprehensive Assessment of Team Member Effectiveness), a web-based tool for team formation and peer evaluation (Layton, Loughry, Ohland, & Ricco, 2010; Ohland et al., 2012). For the first research question, psychological safety (Edmondson, 1999) was used as a dependent variable. This is the average response to a seven-statement questionnaire using a seven-point Likert-like scale. Psychological safety shows how much individuals in teams can contribute their opinion in their teams without fear (Edmondson & Lei, 2014; Kahn, 1990). Students with a lack of psychological safety feel that their efforts are being undermined, whereas students having psychological safety feel their skills are valued and respected (Edmondson, 1999). Psychological safety has been used previously to estimate students' fear of being marginalized (Garvin, Edmondson, & Gino, 2008). Following this, we consider low psychological safety an indicator of marginalization.

For independent variables, we used the "H" dimension of CATME's peer evaluation ("Having relevant knowledge, skills, and abilities") (Ohland et al., 2012). We do not include students' self-ratings since we focus on how others treat students based on how they perceive them. To control for some other factors likely to influence the psychological safety, our regression also included gender, race, and citizenship status as independent variables (See Table 1 for more details of how these were measured). For the second research question, we used CATME's "C" dimension ("Contributing to the team's work") and "I" dimension ("Interacting with teammates") as the most germane measures of team skill in first-year students. We used students' relative ratings of others to self in CATME's "H" dimension as evidence of a student "ranking self against others" from the model by Leonardi, Jackson, and Diwan (2009):

O/S = (Student's average skill rating by others) / (Students' skill self-rating)

Based on the work of Kruger and Dunning (1999), we would expect students with more team skill (higher ratings on the "C" and "I" dimensions) to have less biased self-assessments (a higher ratio of ratings of others to self-ratings). Thus, the "O/S" variable is created in such a way as to expect a direct relationship to the "C" and "I" ratings.

Results

Results for the first research question are presented in Table 2. “Having relevant knowledge, skills, and abilities” is the third factor (after being Black or an International student). Students with more skills feel more psychologically safe, so we find evidence that students with lower skills are marginalized. We measure effect size by Cohen’s $f^2 = R^2/(1-R^2) = 0.1$. The common interpretation of f^2 is that 0.02 is a small effect, 0.15 a medium effect, and 0.35 a large effect, so our model has a small-to-medium effect size.

Table 2: Predicting psychological safety of students based on the skills

Variable	*B*	*SE B*	*β*
Intercept	5.12**	0.12	_
Race (Black)	-0.38*	0.13	-0.07
International	-0.33**	0.06	-0.16
Skill	0.23**	0.03	0.20
Race (Asian)	-0.17*	0.06	-0.09
Race (Hispanic)	-0.09	0.06	-0.04
Race (Native)	0.09	0.42	0.01
Race (Other)	-0.09	0.11	-0.02
Gender (Female)	-0.04	0.04	-0.02
Gender (Other)	-0.01	0.24	-0.001
R^2		0.09	
F for change in R^2		14.14	

Note: B is un standardized beta, SE B is the standard error for the unstandardized beta, and *β* is the standardized beta. *$p < .001$, ** $p < .0001$

We present the results from the second research question Tables 3 and 4. There is evidence that an increase student engagement with the team’s work (C rating by others) and teammates (I rating) is related to a reduction in self-ratings relative to how the student is perceived others (O/S, H peer ratings/H self-ratings). Again, effect size is measured by Cohen’s f^2, which is 0.11 and 0.1 for these models, again resulting in a small to medium effect size.

Table 3: Predicting other to self-rating of students based on the CATME Dimension “C”

Variable	*B*	*SE B*	*β*
Intercept	0.66*	0.03	_
Contributing to the team’s work	0.10*	0.01	0.31
R^2		0.10	
F for change in R^2		154.72	

Note: B is un standardized beta, SE B is the standard error for the unstandardized beta, and *β* is the standardized beta. *$p < .001$

Table 4: Predicting other to self-rating of students based on the Interacting with Teammates

Variable	*B*	*SE B*	*β*
Intercept	0.60*	0.04	_
Interacting with teammates	0.11*	0.01	0.30
R^2		0.09	
F for change in R^2		141.12	

Note: B is un standardized beta, SE B is the standard error for the unstandardized beta, and *β* is the standardized beta. *$p < .001$

Discussion

The results from our first research question are somewhat jarring taken as a whole. As mentioned earlier, these effects can be additive—a student who is perceived to be in more than one marginalized group could experience multiple penalties to psychological safety. A Black student who is perceived to have lower skills could experience both effects, and a Black student from Ghana who is perceived to have lower skills could experience all three effects. This is reminiscent of the "double-bind" experienced by minority women in STEM fields (Malcom, Hall, & Brown, 1976). Based on the results, as team members' perceptions of a student's skill decreased by 1 point, that student's psychological safety decreased by 0.23 point. On its own, the effect size of this phenomenon is moderate. Yet because of the possible compounding with other factors, it can contribute to a strong effect size. It might be hypothesized that the lack of a relationship between gender and psychological safety is due to a team formation strategy that avoids isolating female students in teams. Whereas the same strategy is employed in the case of the racial composition of teams—to avoid isolating students likely to be minoritized based on race/ethnicity, Table 1 shows that there is more gender diversity than racial diversity in the population studied, so this strategy may simply be more effective in mitigating gender effects.

Students reported by peers as making less of a contribution and/or not as good at interacting with teammates showed a greater tendency to overestimate their self-assessment than students who made greater contributions and/or were better able to interact with teammates. This has implications for faculty who use peer evaluation ratings in adjusting grades for individual contributions to team activities. Consistent with the use of instruments that provided an antecedent to the design of CATME's behaviourally anchored rating scale for peer evaluation (Brown, 1995; Kaufman, Felder, & Fuller, 2000), CATME provides an adjustment factor that is a student's average rating divided by the team's average rating, after the behavioural anchors have been converted to a numerical scale. The CATME system provides this adjustment factor both with and without the student's self-rating included, so instructors can consider the disparity. Noting that while the CATME instrument itself has been evaluated in multiple contexts (Ohland, et al., 2012), no validation of the use of the adjustment factor has been published, so it may be more appropriate to use CATME's peer evaluation tool for monitoring teams, providing feedback, and diagnosing certain patterns of performance and rating behaviour.

Conclusion

Since engineering students have some counterproductive practices, and it takes industry managers' time and energy to teach newcomers proper working practice, it would be necessary to know what counterproductive practices they have and make efforts to correct them in the first year of study. In this study, we found evidence that we are able to measure some of these counterproductive practices through data collected in peer evaluations and a measure of psychological safety. Our first finding offers instructor an opportunity to diagnose possible instances of marginalization. Our second finding is more important to consider in how data from the peer evaluations is used.

Implications and Future Work

Correcting any counterproductive practices in the first year of study would benefit engineering education because it would be harder to correct them at the senior level, and we also would have engineering graduates who need less education about correct working practices. An important extension of this work would be to explore whether various interventions—such as experience in engineering practice—affect the result.

Limitations

In our study, some independent variables were peer ratings of team skills, while we have no independent "true score" as a measure of team skills. However, the "true score" can be kind of consensus between different people (Kruglanski, 1989) which here is rating of different peers. Since measuring true teamwork skill is difficult even using experts, we argue that this limitation is due to the nature of our study and not a weakness of design. Nevertheless, qualitative research and observational data could provide valuable additional information to interpret our findings. We are also limited in that this research was conducted at a single, predominately White institution in the United States. Our results, and in fact the model developed by Leonardi, Jackson, and Diwan (2009), may be applicable primarily within the U.S. culture. Noting that conversations with academic staff in other countries including Australia seem to indicate that some of these misconceptions are common elsewhere, we are encouraged to believe that our findings have the potential to generalize.

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