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Social Belonging and First-Year Engineering Mathematics: A Collaborative Learning Intervention

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Social Belonging and First-Year Engineering Mathematics:

A Cooperative Learning Intervention

Purpose

This research examined the relationship between engineering students' sense of belonging and performance in a remedial first-year math class and investigated how a cooperative learning intervention might improve both students' affective and academic experience in this course. Many universities offer academic interventions to support at-risk engineering freshmen. At our university, *Introductory Calculus for Engineers* targets students identified as under-prepared or struggling in the freshman engineering math course. Although the intervention helps some students, there are many for whom it is unsuccessful, likely because social, psychological, and situational factors contribute to underperformance. Specifically, feelings of belonging and learning environment likely contribute to variability in achievement.

In two studies, we examined the relationship between perceived belonging and course performance for first-year engineering students at a large urban public university. In Study 1, participants enrolled in *Introductory Calculus for Engineers* were surveyed about their perceptions of belonging to college at the end of the 2014 fall semester. A positive relationship between belonging and achievement was identified.

With the aim of increasing belonging, and thereby achievement, Study 2 was conducted in the subsequent semester, to pilot a cooperative learning (CL) intervention in the same course. Students were surveyed at the beginning and end of the semester to determine whether CL boosted students' sense of social belonging and belonging to math, and whether these perceptions were associated with grades. Furthermore, participants' attitudes towards CL were examined.

Active learning strategies, such as CL, are consistently shown to increase student engagement and learning in STEM classrooms. This study demonstrates that part of the instructional method's effectiveness is likely due to its promotion of a sense of belonging among students. Perceptions of belonging may be especially important for students who are at risk of failing or withdrawing from first-year gateway courses to their major.

Background

Rates of retention in STEM programs hover around 50%, due in large part to first and second year gateway courses, from which students fail or drop out in large numbers.[1] Innovative teaching methods have been recommended as a vehicle for increasing achievement and retention in undergraduate STEM education.[2] Specifically, incorporation of new technology, inquiry-based projects, collaborative learning, and conceptually-oriented tasks are some ways in which STEM coursework is being reimagined to meet the challenge of improving learning outcomes for undergraduates in STEM courses.[3]

Even when academic interventions fall short of producing the desired gains in course achievement, they may have other beneficial consequences, such as improvement in social and psychological factors. For example, belonging uncertainty may cause students to interpret personal challenges on campus as indicative that they do not fit in in college.[4] In particular, historically underrepresented groups in STEM, such as women, minorities, and first-generation college students, may underperform in courses in which they feel stigmatized or to which they feel they do not belong.[5,6,7]. We hypothesize that changes to the learning environment that increase belonging may help reduce feelings of self-doubt and boost persistence in the face of challenge.

Social Belonging

Social belonging has been defined as a feeling of acceptance and membership in a group.[7] Its role in facilitating learning has been well-established, particularly for students who have doubts that they fit in. For example, Walton & Cohen[8] found that a one-time social-belonging intervention altered African American college students' construal of adversity on campus, resulting in a significant increase in GPA over a control group, an effect that endured for the next three years. The intervention consisted simply of students reading survey results and brief messages from older students on campus, indicating that doubts about belonging are common to all students and fade with time. A similar intervention, used to target women in male-dominated engineering majors, succeeded in raising women's engineering GPAs to males' levels and improved their attitudes towards academics and daily adversities.[9] Both of these studies and others (e.g., [10, 11]), illustrate the importance of social belonging to college students who are historically underrepresented in their academic environments. A sense of belonging improves self-efficacy for learning and promotes social integration for students who are insecure about their place on campus or in their chosen major. Critically, a sense of belonging reduces vulnerability to *stereotype threat* – the achievement decrement for students in negatively-stereotyped groups that results from awareness of the expectation that they will underperform relative to their peers.[6]

Belonging can be domain-specific, and instruments for measuring belonging in specific subject areas have been developed.[12] For example, *math belonging* is associated with increased confidence in one's own math abilities and belief in the utility of math. Good, Rattan, & Dweck[7] found that women who perceived a gender stereotype in their college calculus classes experienced a drop in math belonging, and that drop predicted lower course grades and intent to pursue math in the future.

Information about belonging is provided by cues from students' learning environment .[7] Thus, a learning environment that increases belonging by encouraging collaboration and reducing competition may increase achievement. Cooperative learning is one such instructional strategy that has been shown to improve affective outcomes, such as self-efficacy in students.[12]

Cooperative Learning

Group learning can take a variety of forms, and many of the terms to describe these forms are used interchangeably (e.g., cooperative, collaborative and problem-based learning[13]). These group learning varieties have been found to increase student motivation and achievement, but differ in terms of level of task structure, the assignment of roles to group members, use of shared materials, involvement of instructors, and built-in reflection on the process. One particular group learning structure used in the current study, *cooperative learning* (CL), typically groups students with one to three others to work together to reach a mutual goal that requires the efforts of all group members. Interdependence among group members is fostered by having students take on different roles in the group process upon which the others depend, or by having groups share one set of materials. The instructor in CL often actively facilitates the group interaction; activities are timed and students are guided through them together. There is attention to process; for instance, students may be asked to reflect on the group's role in their learning.[13]

There are reasonable arguments for and against structuring classwork cooperatively. Cognitive load theorists disagree about the impact of CL on working memory. Some scholars have offered collaboration as an antidote to overtaxing working memory during cognitively demanding activities, while others have argued that CL imposes an additional burden on working memory, as resources are diverted to organizing and communicating within the group.[14] Yet, there is broad agreement that CL elicits cognitive benefits, by provoking verbal elaboration,[15] multiple representations of a problem or viewpoints of an issue,[16] and critical thinking.[17] Webb's[15] systematic analysis of group processes at work in small group learning determined that task-related verbal interactions conferred the most important benefit. Specifically, students who explained how to solve a problem to their group benefited from the cognitive restructuring they engaged in as they reorganized the information they explained. Moreover, the explicit emphasis on problem-solving procedures and verbalization of methods and strategies that occur in small groups encourages metacognition.[17]

Prior research has shown that CL has positive effects on achievement. CL in college remedial math has resulted in higher course grades and a greater chance of passing for students who worked in groups.[18] Engineering students' self-reported use of collaborative learning strategies have been found to be predictive of course performance.[19] The effects of CL on achievement are primarily manifested in improved scores on instructor-created exams, as compared with standardized assessments. The method by which groups are composed, whether through self-selection, random assignment, or non-random assignment by instructor, does not impact these findings.[20] Slavin[21] contended more than 30 years ago that the most important factor in determining the benefits of CL on achievement were the incentive structure of the class, with students who were awarded both individually and as a group producing the highest gains. In a meta-analysis on the effects of small-group learning on transfer performance, in particular, average effect sizes of 0.30 were found.[22] Considering the numerous factors impacting learning, this effect should be taken seriously.

In addition to achievement, there are substantial motivational benefits to CL. In a summary of results from meta-analyses on all the studies on cooperative learning conducted up to 1989, Johnson, Johnson, & Smith[17] found improvements in motivation and attitudes for students working cooperatively. Students were more prone to like the subject matter they were studying, the professors instructing them, and the courses they were taking. The students developed mutual interdependence and intrinsic motivation for their own and classmates' success. A more recent meta-analysis of small-group learning on STEM majors in college courses found effect sizes of 0.55 for development of positive attitudes, meaning that an increase of half of a standard deviation in positive attitudes resulted from small-group learning.[20] Furthermore, students' confidence in their ability to learn course material, or *self-efficacy*, is related to students' use of CL strategies.[19] Most relevant to the experience of at-risk students, a CL environment improves students' ability to manage difficulties and persist following failure.[23] An effect size of 0.46 on student persistence is typical in the studies of CL in post-secondary education, an effect strong enough to reduce attrition from STEM courses and programs by 22%.[20]

Current Studies

In Study 1, we hypothesized that students' perceptions of social belonging in college would be positively related to their performance in a remedial engineering mathematics course. In Study 2 we predicted that the same relationship between social belonging and performance in the remedial engineering math course would be present, and we further hypothesized that a CL instructional environment would foster a relationship between a domain-specific sense of belonging to math and academic achievement. Moreover, we examined changes in interpersonal and motivational variables from the beginning to end of the semester that we hypothesized would be influenced by the CL environment.

Study 1

Methods

Participants

All students in *Introductory Calculus for Engineers (ENGR 190)* were invited to participate in this research by filling out a survey at the end of the semester. The survey was administered to these students during a separate, required course that introduces students to the engineering profession. *ENGR 190* is a remedial course for students considered unprepared (based on entrance exam scores) to enter *Engineering Analysis I (ENGR 101)*, a required first-semester calculus course for engineering majors. Students enrolled in *ENGR 190* are more likely to have lower grades and to drop out of the engineering major than their peers who begin with ENGR 101.[24] All first-time, full-time freshmen who completed the survey (80.99% response rate), who earned a grade in *ENGR 190* in the fall of 2014, and for whom ACT-Math scores were available, were included in the study ($N = 113$). The average ACT-Math score of the sample was 26.47 ($SD = 1.81$); 35 were female (31%) and 13 (11.5%) were African-American, Hispanic/Latino, or two or more races. Of note, this remedial course was composed of more female and minority students than the freshman cohort as a whole, $\chi^2(1, N = 462) = 4.859$, $p = .028$ (see Table 1).

Procedure

Students completed the survey questions during class time during Week 13 of the 16-week semester. The questions were given as part of a larger research study intended to identify factors that predict student performance and retention in the engineering major. At the beginning of the survey, students were informed that completing the questions was voluntary and were given the option to consent or decline to participate in the survey with no penalty. In addition, students were given the option to opt-out of this research at any time by informing the study contact.

Table 1

Descriptive Statistics for Demographic Variables in Cohort (N = 462)

	Non-remedial Calculus Fall 2014 *(n = 304)*		Remedial Calculus Fall 2014 *(n = 158)*	
	Number	Percent of Class	Number	Percent of Class
Female	64	21.1%	38	24.1%
African-American, Hispanic/Latino, Multiracial	20	06.6%	20	12.7%

Note. First-generation college status data was not available.

Measurements

Belonging Uncertainty

The four-item Belonging Uncertainty scale was used to assess students' perceptions of belonging in college (sample Cronbach's $\alpha = .79$).[8] A sample item reads, "When I face difficulties in college, I wonder if I will really fit in." All the items on the scale are listed in the Appendix. Each item was answered on a five-point Likert scale (*Not at all true* = 1 to *Completely true* = 5). After reverse coding one item, items were averaged to form a composite measure of belonging uncertainty, with higher scores reflecting more uncertainty (i.e., less belonging).

Outcome Measure

An average of the five course exams served as the measure of course performance. Any exam with a score of zero was eliminated from the average so that the average reflected the student's effort and ability, not attendance.

Results & Discussion

All analyses required a p-value less than .05 in order to meet the threshold for statistical significance. A linear regression was used to determine the relationship between belonging uncertainty and average exam grades, while controlling for prior mathematics ability (i.e., ACT-Math scores). Both predictor scores were mean centered. As shown in Table 2, the greater students' belonging uncertainty, the more poorly they performed in the course. On average, an increase of one point on the belonging uncertainty scale (indicating more doubt about belonging) results in a 3.6 percent point decrease in exam average. ACT-Math scores were not a significant predictor of exam average, likely because of limited variability, as students were assigned to the course if their ACT scores fell below a cutoff point. Belonging uncertainty explained 7% of the variance in exam grades, a small but significant proportion, when considering the multiplicity of variables that affect course performance, $\Delta R^2 = .06$, $F(1, 110) = 7.35$, $p = .008$.

Table 2

Results from Linear Regression Model to Predict Exam Average (N = 113)

	B (unstandardized)	S.E.	β (standardized)	*t*	Sig	95% CI
ACT-M	.005	.006	.085	0.92	.360	[-.006, .017]
Belonging Uncertainty	**-.036**	**.013**	**-0.25**	**-2.71**	**.008***	**[-.062, -.010]**

Notes. CI = confidence interval
*$p < .05$

These results indicate that students' insecurities about belonging in college negatively impact course performance. Having identified doubt about social belonging as a potential barrier to academic achievement in our population of engineering freshmen, in Study 2 we sought to identify factors that might increase belonging, and consequently, performance.

Study 2

Given what we learned in Study 1 from examination of the freshman cohort of *ENGR 190* students, we designed a subsequent study to look at the students who would be enrolled in *ENGR 190* in the following semester. We had identified a link between belonging and achievement in the previous semester; therefore, we introduced a CL intervention to the course that we believed would promote social belonging and belonging to math. We predicted that belonging would increase over the course of the semester and be predictive of course performance outcomes. Given the motivational and interpersonal benefits of CL, we also predicted that attitudes towards and experiences with CL would increase from the beginning to end of the semester. Such findings would suggest an important role of social belonging to academic performance in a remedial gateway mathematics course, and provide preliminary evidence that CL may help to increase perceptions of belonging, in addition to other motivational factors.

Methods

Participants

All 35 students enrolled in the spring 2015 section of *Introductory Calculus for Engineers (ENGR 190)* were invited to participate in the study, which occurred during the course of their regular instructional period. The majority of students in this course section could be considered at high-risk of dropping out of the major, having received grades of D, F, or W from either ENGR 101 or 190 previously. A minority of students were joining the major late in their first year and had missed the fall calculus class or were non-engineering majors.

The syllabus contained a consent statement, notifying students of the study and offering them an opportunity to opt out of having their course materials used for research purposes. Students were included for analysis if they completed both a pre- and post-survey and earned a final grade in the class (N = 18). Completion of the survey was voluntary; no rewards or credit towards grades were offered as incentives. Of the original 35 students, seven withdrew from the course early in the semester. Of the remaining 28, 20 took the post-test, but two had not taken the pretest. Students in the resulting sample had earned a D+ or lower in their previous semester of engineering math (13 students), were non-majors (2 students) or had transferred into engineering in the fall (3 students). Demographic information for the sample is provided in Table 3.

Table 3

Descriptive Statistics for Demographic Variables in Sample (N = 18)

	Number	Percent of Sample
Female	5	27.8%
African-American, Hispanic/Latino, or Multiracial	3	16.7%
First-Generation College Student	3	16.7%

[a]One participant did not provide racial identification.

Survey

In their first and last class meetings, all students were given 15-20 minutes to complete the online survey measures as part of a larger survey on factors impacting engineering mathematics performance. The surveys examined perceptions of belonging and other factors hypothesized to be impacted by experience with cooperative learning during the semester: perceptions of belonging uncertainty,[8] sense of belonging to math,[7] collaborative activity,[19, 25] and attitudes towards collaboration.[26, 27]

Measurements

Belonging Uncertainty

The same Belonging Uncertainty scale as used in Study 1 was used in Study 2 (pre-survey Cronbach's α = .74, post-survey α = .91).

Math Sense of Belonging

The Math Sense of Belonging scale consisted of 30 items measuring domain-specific feelings of belonging to math, including feelings of membership, acceptance, affect, desire to fade, and trust in a math setting [7] (pre-survey Cronbach's α = .89, post-survey α = .94). A sample item reads, "When I am in a math setting I feel like I fit in." All items on the scale are listed in the Appendix. Each item was answered on a seven-point Likert scale (*Strongly disagree* = 1 to *Strongly agree* = 7). After reverse scoring the 12 items that measure the inverse relationship, items were averaged to form a composite measure, with higher scores reflecting a greater sense of math belonging.

Student Perceptions of Classroom Knowledge-Building (SPOCK)

We used the five-item collaborative learning subscale of the SPOCK[19, 25] (pre-survey Cronbach's $\alpha = .97$, post-survey $\alpha = .91$). On the pre-survey, items were preceded by the question, "How often have you experienced the following in previous math classes you have taken?" On the post-survey items were preceded by the question, "How often did you experience the following in this class?" A sample item reads, "My classmates and I actively worked together to help each other understand the material." All items are listed in the Appendix. Each item was answered on a five-point Likert scale (*Almost never* = 1 to *Almost always* = 5).

Collaborative Learning Attitudes

The Collaborative Learning Attitudes scale was adapted from two instruments[26, 27] to assess students' attitudes toward CL (pre-survey Cronbach's $\alpha = .95$, post-survey $\alpha = .94$). All 14 items were answered on a five-point Likert scale (*Strongly disagree* = 1 to *Strongly agree* = 5). The pre-survey items were preceded by the statement, "In previous classes…" The post-survey items were preceded by the statement, "In this class, when I worked in a group…" A sample item reads, "Group members both gave and received feedback from each other."

Cooperative Learning Intervention

Students participated in a CL environment during their regular instructional period over the course of the semester. The course met for seventy-five minutes twice a week, in a room recently renovated to support cooperative and collaborative learning. The room contains three tables, with each table having nine chairs and three LCD 27 inch monitors that display notes from the instructor. At each of the 28 class meetings, students were randomly assigned to groups of three and worked together. At the beginning of each class, students individually reviewed the assigned reading and answered questions on paper about the most important concepts; then they discussed these questions in their groups. Next, the professor and undergraduate teaching assistants (UTAs) led the small groups through five or six problem-solving activities at their own pace. Groups were given one copy of a worksheet with one problem on it; when they signaled completion, a UTA provided the group with feedback on their solution. The group had to arrive at the correct answer before they were given the next problem. Instructors used language such as, "Ask three, then me," to encourage group members to utilize each other and their resources before seeking guidance from the professor or UTAs; solutions were not given to the students, but the instructor or UTA would give increasing guidance until the group was able to reach the solution. Each group member took on a role for that class period, either elaborating on the question by connecting it to prior knowledge, recording the group's work, or verifying the answers and that all members of the group understood the solution. The roles rotated among group members after every problem. Most classes ended with a one-minute reflection on the collaborative learning process that day. An example of a reflection prompt was: *Reflect on how you contributed to the learning of your group members today*. Fifteen percent of the course grade was awarded for group participation. A quiz was given each week, and a test was given after every two quizzes; these were assessed at the individual level.

Problem solving activities ranged from computational problems such as:

Solve the logarithmic equation. $2\ln x - \ln(2x-3) = \ln 2x - \ln(x-1)$

To work problems such as:

Solve the problem algebraically. *Define all variables, write an appropriate equation and solve.* The perimeter of a rectangular garden is 32 feet. The length of the garden is 4 feet less than three times the width. Find the dimensions of the garden.

Outcome Measures

The final grade in the course served as our primary dependent variable. Eighty-five percent of the final course grade was computed from the average score for the quizzes and exams in the class. Fifteen percent of the final grade was awarded for the collaborative activities completed during class. Four pre-to-post survey measures served as interpersonal and motivational dependent variables (i.e., belonging uncertainty, math belonging, engagement in collaborative learning, and attitudes toward collaborative learning).

Results & Discussion

Regression analyses were used to determine the strength of relationships between the belonging variables at post-survey with final course grades, while controlling for prior ability (i.e., ACT-M scores). As shown in Tables 4 and 5, at the end of the semester, greater math belonging was associated with significantly higher course grades, and less belonging uncertainty about college was associated with marginally higher course grades. Math belonging explained 44% of the variance in course grades after controlling for prior math ability, $\Delta R^2 = .44$, $F(2, 14) = 5.41$, $p = .018$. One unit of change on the math belonging scale resulted in an 8.1% increase in final course grade. The significance of belonging uncertainty as a predictor of course grade was marginal, and explained 23% of the variance in course grades after controlling for prior math ability, $\Delta R^2 = .23$, $F(2, 14) = 2.14$, $p = .154$. Each unit decrease in belonging uncertainty was associated with a 4.4% increase in course grades.

In order to test our hypotheses about changes to students' perceived belonging uncertainty, math belonging, collaborative learning interactions (SPOCK), and collaborative learning attitudes from the beginning to end of the semester, paired sample *t*-tests were used. Because all predictions were made a priori and all tests were independent, the acceptable level for Type I alpha was set at .05. Descriptive statistics for all scales are presented in Table 6. At the semester's end, students reported greater math belonging, $t(17) = -2.83$, $p = .011$, higher ratings of collaborative interactions with their classmates, $t(17) = -4.99$, $p < .001$, and better attitudes towards collaborative learning, $t(17) = -2.70$, $p = .015$. Decreases in belonging uncertainty did not reach statistical significance, $t(17) = 1.40$, $p = .180$.

Table 4

Results from Linear Regression Model to Predict Course Grade on Math Belonging (N = 17[a])

	B (unstandardized)	S.E.	β (standardized)	*t*	Sig	95% CI
ACT-M	.009	.007	.292	1.40	.183	[-.005, .024]
Math Belonging	**.081**	**.025**	**.677**	**3.25**	**.006***	**[.028, .135]**

Note. CI = confidence interval.
[a]One student's ACT score was not available from the Office of Institutional Research.
*$p < .05$

Table 5

Results from Linear Regression Model to Predict Course Grade on Belonging Uncertainty

	B (unstandardized)	S.E.	β (standardized)	*t*	Sig	95% CI
ACT-M	.005	.008	.152	.645	.529	[-.011, .021]
Belonging Uncertainty	**-.044**	**.022**	**-.474**	**-2.02**	**.063**	**[-.091, .003]**

Note. CI = confidence interval

Table 6

Descriptive Statistics and Effect Sizes for All Scales (N = 18)

	Pre-Survey *M (SD)*	Post-Survey *M (SD)*	$\hat{d}$ (calculated using pre-survey *SD*)
Belonging Uncertainty	2.36 (0.87)	2.17 (1.15)	-.22
Math Belonging	4.45 (0.66)	4.82 (0.87)*	.56
Collaborative Activity (SPOCK)	3.16 (1.08)	4.57 (0.51)*	1.31
Collaborative Attitudes	3.62 (0.77)	4.18 (0.50)*	.73

Note. *$p < .05$

Decreases in belonging uncertainty were smaller than the changes for the other variables from pre-to-post survey. It seems likely that the difference was too small to detect given the low power for this measure attained from our sample, $1-\beta = .25$ (G*Power 3.1.9.2[30]). Unfortunately, our sample size was constrained by the limits of class enrollment and persistence. However, the significant change in math belonging is a more relevant measure since the course was a math course; belonging uncertainty asks about perceptions of social belonging to college in general. Power for the math belonging test was medium-large, according to Cohen[28, 29], at 1-β = .76.

General Discussion

These studies demonstrate that a greater sense of social belonging is associated with higher grades in a remedial engineering mathematics course. Furthermore, perceptions of math belonging, and attitudes about and engagement in collaboration, increased over the course of a semester in an instructional environment that encourages cooperation among students. Of interest, the sample in these studies was students at risk of failing out of engineering, a population for whom academic interventions are not always successful. These findings are consistent with the idea that social-psychological factors act as barriers to student achievement in engineering, namely, feelings of doubt that one fits in to the academic environment.[8, 9, 10, 11] If this uncertainty can be lessened by an instructional environment that produces greater social cohesion, then there are important implications for pedagogy in engineering education.

Limitations and Future Research

The current findings provide correlational evidence that social belonging is related to course performance in engineering mathematics classes. Notably, even when controlling for mathematics ability, social belonging predicted 7% and 23% of the variance in course performance in Studies 1 and 2, and math belonging predicted 44% of the variance in Study 2, supporting the idea that psychological factors are important above and beyond ability measures. However, due to the correlational nature of these findings, we cannot know whether social belonging causes these differences in course grades. For example, higher grades could lead students to perceive greater social belonging. This possibility seems less likely, given that we controlled for prior ability, but cannot be ruled out. Future research should expand the size of the sample used here and seek to clarify the directionality of these findings.

Similarly, in Study 2, the lack of a comparison condition in which CL was not used limits the conclusions that may be drawn from these results. Students' attitudes about belonging and collaborative learning increased from the beginning to end of the semester in a classroom using a CL instructional method. However, without a comparison group, we cannot be certain how students' perceptions would change in other classroom contexts. It is likely that students' reported perceptions at the beginning of the semester were based on previous experiences in mathematics and/or college classes, and yet these perceptions remained comparatively low. Given that these perceptions improved by the end of the semester, it seems likely that students' experiences in this particular course may be at least partially responsible. However, future research is needed to compare the causal impact of a CL environment on perceptions of belonging and collaboration, compared to other instructional methods.

To control for these limitations, future research should target social belonging experimentally, and compare students' course grades as a result of the belonging intervention. Such interventions have been used successfully in the past with college students[8, 9, 10, 11] (see Yeager & Walton for a review[31]). In addition, future research should experimentally manipulate the instructional method used in the course, with CL as one technique, and business-as-usual (e.g., lecture or emporium methods) as a comparison condition. We are currently conducting such experimental research, based on the evidence reported here.

Despite the promising benefits of CL, there are particular challenges that might complicate collaboration in STEM college classes, such as large class sizes, physical limitations of lecture halls, and the perception that lecture is the most expedient method for imparting instruction. Yet, there is a mandate to teach professional skills to STEM students, and these overlap with the skills that are utilized in collaboration (e.g., communication and teamwork).[32] Classroom studies such as this one may provide further impetus to faculty to implement collaborative learning in their courses.

The small sample size in Study 2 is also a potential limitation. It is encouraging to note that, despite the small number of participants in Study 2, the increase in math belonging and collaborative learning attitudes was statistically significant. Moreover, the regression results parallel those of Study 1, for which a large sample was used.

The current findings may also be limited to characteristics particular to the sample we tested. These studies examined the performance of students who were unable to meet the standard for acceptance in the first mathematics course in the engineering sequence. These students demonstrated lower ability on a standardized test of mathematics achievement (ACT-M). However, these students may have encountered other psychological barriers that limited their performance prior to the course. For example, factors other than math ability contribute to insecurity about belonging (e.g. stereotype threat[7]). It is noteworthy that these courses included a higher proportion of minority students in the engineering major (e.g., women, racial minorities, and first-generation college studies), when compared to students in the non-remedial engineering mathematics course. In addition, the assignment to a remedial course in the first year of an engineering program may produce a stigma that students find difficult to overcome. Thus, demonstrating the impact of social belonging and CL for these higher-risk students is especially important, because it offers a potential mechanism by which these students' success may be enhanced. However, these benefits may extend to other students as well. Future research is needed to determine the impact of social belonging and CL in non-remedial mathematics courses.

Conclusions

In summary, these findings point to a potential mechanism that may improve performance in gateway engineering mathematics courses: social belonging. Moreover, these results suggest that CL methods may increase these perceptions of belonging, which are associated with course performance. Thus, the learning environment may impact more than knowledge gains, but also perceptions and attitudes that bolster the learning experience for at-risk students. Prince[33] cautioned that educational interventions typically produce modest effect sizes and that any resulting gains must justify the amount of work required to restructure a course. He made a case, based on a review of the empirical evidence, that active learning techniques that allow students to work together (e.g. cooperative and collaborative learning) were well worth the effort for engineering faculty. The advantage to students learning in these environments is not solely manifested in increases in achievement, but also in professional skillbuilding. ABET requirements specify that engineering programs must prepare students for teamwork, and instructional environments such as the one described here provide a natural setting in which students can develop interpersonal skills. In our Study 2, the change in attitudes and engagement from beginning to end of semester resulted in effect sizes that were three-quarters of a standard deviation and one and one-third standard deviation greater, respectively. We have clearly outlined a class structure based around cooperative learning that reduced competition among students and promoted discussion with peers during problem-solving. Further, students' perceptions of belonging improved in this environment and were predictive of course outcomes.

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Appendix

Belonging Uncertainty Scale

1. Sometimes I worry that I do not belong in college.
2. I am anxious about whether I fit in at college.
3. I feel confident that I belong in college. (reverse-coded)
4. When I face difficulties in college, I wonder if I will really fit in.

Math Sense of Belonging Scale

When I am in a math setting…

1. I feel that I belong to the math community.
2. I consider myself a member of the math world.
3. I feel like I am part of the math community.
4. I feel a connection with the math community.

5. I feel like an outsider. (reverse-coded)
6. I feel accepted.
7. I feel respected.
8. I feel disregarded. (reverse-coded)
9. I feel valued.
10. I feel neglected. (reverse-coded)
11. I feel appreciated.
12. I feel excluded. (reverse-coded)
13. I feel like I fit in.
14. I feel insignificant. (reverse-coded)
15. I feel at ease.
16. I feel anxious. (reverse-coded)
17. I feel comfortable.
18. I feel tense. (reverse-coded)
19. I feel nervous. (reverse-coded)
20. I feel content.
21. I feel calm.
22. I feel inadequate. (reverse-coded)
23. I wish I could fade into the background and not be noticed. (reverse-coded)
24. I try to say as little as possible. (reverse-coded)
25. I enjoy being an active participant.
26. I wish I were invisible. (reverse-coded)
27. I trust the testing materials to be unbiased.
28. I have trust that I do not have to constantly prove myself.
29. I trust my instructors to be committed to helping me learn.
30. Even when I do poorly, I trust my instructors to have faith in my potential.

SPOCK Collaborative-Learning Subscale

In this class…

1. My classmates and I actively worked together to complete assignments.
2. My classmates and I actively worked together to help each other understand the material.
3. I got helpful comments about my work from other students.
4. My classmates and I actively worked together to learn new things.
5. My classmates and I actively shared ideas.

Collaborative Learning Attitudes Scale

In this class, when I worked in a group…

1. My group developed clear collaborative patterns to increase team/group learning efficiency.
2. My group trusted each other and worked toward the same goal.
3. My group members clearly knew their roles during the collaboration.
4. My group set clear goals and established a working norm.

5. My group members replied to all responses in a timely manner.
6. My group members communicated with each other frequently.
7. I trusted each group member to complete his/her work on time.
8. Group members both gave and received feedback from each other.
9. Communicating with group members regularly helped me to understand the collaborative activities better.
10. My group members encouraged open communication with each other.
11. My group members communicated in a courteous tone.
12. The support from the instructor or teaching assistant helped my team to reduce anxiety among team members.
13. The instructor or teaching assistant acted as a referee when our members could not seem to resolve differences.
14. My team received guidance on the collaborative activities from the instructor or teaching assistant.