The Importance of Teaching Assistant Support and Interactions in Student Engagement

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Abstract

Prior research on the impact of instructors on student engagement has focused primarily on faculty, but teaching assistants (TAs) are also important. This study examined relationships among TA support, TA-student interactions, and student engagement and also sought to identify groups of students for whom TA support and TA-student interactions appeared particularly important. Hierarchical linear regression models using cross-sectional survey data from over 750 students at a single large public institution were used to assess relationships between TA support, TA-student interactions, and three forms of student behavioral engagement. TA support positively and significantly predicted all engagement variables. For effort and participation, TA-student interactions positively and significantly predicted engagement while for attention, this relationship was significant but negative. Some interaction effects involving gender, race, mother's education, and U.S. status were also significant. Our findings underscored the importance of TAs in the student academic experience.

Keywords
engagement; graduate teaching assistant; motivation; academic support, academic integration

Introduction

Teaching Assistants (TAs) play significant roles in undergraduate instruction in the United States. In 2017, the Bureau of Labor Statistics estimated that 131,490 graduate students were employed as teaching assistants in the United States, and of these, 126,340 individuals were employed at colleges, universities, and professional schools, comprising 4.15% of the university workforce (Bureau of Labor Statistics, n.d.). In undergraduate engineering courses, TAs perform a wide variety of tasks including lecturing, leading lab sections, conducting review sessions, facilitating discussions, holding office hours, and providing technological support. In some fields like biology, TAs teach over 90% of lab sections at research universities (Gardner & Jones, 2011). Many of these lab sections are associated with first- or second-year courses and are seen as "gateway" courses, which are required for students entering science and engineering majors and in which attrition rates are especially high (O'Neal et al., 2007; Seymour & Hewitt, 2000). In these courses, students frequently have more overall contact with their TAs than with professors, and TAs are therefore a "first line of defense" in instruction, profoundly influencing the effectiveness of faculty and departments in which they serve (Gardner & Jones, 2011; Rushin et al., 1997).

By examining connections between undergraduate student engagement and TA support and TA-student interactions, this study focuses on the critical and unique roles that TAs play in undergraduate instruction in engineering.

Background -- TAs

Given the importance of TAs in STEM education, evidence that TAs and other contingent instructors were less effective than tenure track faculty in teaching undergraduates is concerning (Umbach, 2007). However, previous research has indicated that undergraduates perceive TAs differently than regular faculty, suggesting that TAs may have a different impact on student engagement and learning than faculty do. While students viewed faculty as experienced, organized, and confident but also as strict, boring, and distant, they viewed TAs as interactive, engaging, understanding, and relatable but also uncertain and less confident (Kendall & Schussler, 2012). These significant differences in perception likely led to differences in how students interacted with and engaged with TAs compared to faculty. Thus, the faculty support literature is limited in providing insight into how TA support and TA-student interactions are assocaited with student learning and engagement.

Most studies of engineering and other STEM TAs have focused on TA background characteristics, experiences, and training (e.g. Gardner & Jones, 2011; Prieto & Altmaier, 1994; Reeves et al., 2016; Shannon et al., 1998). While not as numerous as studies of faculty support, studies that specifically focused on TA support nevertheless reaffirmed its importance. For example, in biology courses, TAs provided a level of personalization and enjoyment for students that complemented the more aloof, authoritative, and strict control that undergraduates perceived of instructional faculty (Kendall & Schussler, 2012). A similar study of high-enrollment biology courses at a research-intensive Australian university (Good et al., 2015) found that consistent TA-student pairings enabled mentoring relationships to develop and contributed to gains in student motivation and learning.

Mentoring and other relational support has often expressed via one-on-one interactions between TAs and students. While the benefit of student-faculty interaction for student engagement has been well established by prior literature (Umbach & Wawrzynski, 2005), examination of this effect among TAs and students has been more limited. A study of physics tutorials found that a majority of interactions were initiated by TAs, underscoring the importance of their investment in student experience and engagement (Scherr et al., 2006). The number of times that a TA initiated such interactions with a student as well as the total frequency of interactions were associated with positive student evaluations (Hazari et al., 2003) and student engagement (Scherr et al., 2006, 2006) in physics laboratories. TA-student interactions were also associated with positive student perceptions of their own learning (Wheeler et al., 2017).

Other relational support provided by TAs may also inform student learning and satisfaction. For example, the perception of how amiable, calm, and clear a TA is shaped student satisfaction in laboratory courses in physics (Hazari et al., 2003). In project-based learning in engineering, TAs also played a critical role by providing the relatedness needed to advance competence beyond what was possible in courses with more traditional structure. In contrast, a lack of concern by the TA for student learning or lack of connection between TA and student impaired gains in competence and reduced motivation (Trenshaw et al., 2016). In gateway science courses, TAs impacted lab climate (i.e. how fun and welcoming a lab is), course grades, and student understanding of science careers, which in turn can impact persistence and retention (O'Neal et al., 2007).

This body of literature has underscored the importance of TAs in contributing to student learning but it has also highlighted the different roles that TAs play in student learning compared to regular faculty. This study builds on the limited literature that focuses specifically on TAs by looking at relationships between the types of academic support and interactions TAs provide and student engagement in academic courses.

Background -- Engagement

Student engagement is typically understood to capture the time and effort students give to college activities that lead to positive outcomes, as well as what higher education institutions do to involve students in such activities (Kuh, 2009). Wolf-Wendel et al. (2009) pointed out that engagement is often viewed as potentiating integration. Students become integrated by becoming engaged, being involved, and expending effort that results in positive outcomes.

Student engagement in college life, both social and academic, has been connected to many positive academic outcomes including gains in critical thinking skills (Carini et al., 2006; Gellin, 2003), GPA (Carini et al., 2006), and exam and homework grades (Handelsman et al., 2005). Conversely, lower engagement has been consistently related to withdrawal from college (Hughes & Pace, 2003). And, indirectly, academic and social engagement have been associated with gains in learning through the integration of information (Pike & Killian, 2001). Furthermore, engagement has been shown to have an especially important "compensatory effect" (Kuh et al., 2008, p. 555) for some groups of first-year students, including students of color and students entering college with lower levels of academic preparation (Kuh et al., 2008).

While significant, the relationships between different forms of engagement and academic outcomes can nevertheless vary widely in strength. For example, in a comprehensive study by Carini et al. (2006), the effort (i.e. a form of behavioral engagement) put forth by students in completing readings and assignments was strongly correlated to standardized test scores. But, working with other students on projects during class was not correlated to learning at all, and preparing two or more drafts of papers was more weakly correlated with learning. A meta-analysis by Robbins (Robbins et al., 2004) of psychosocial and study skills confirmed the importance of class-related behavior in that the effort students put into homework assignments and preparing for tests was moderately related to retention, and the motivation to achieve was strongly related to retention. Another study that focused on developing measures of engagement for specific courses demonstrated more consistent positive associations with academic outcomes than those which study engagement more broadly (Handelsman et al., 2005).

In combination, these studies support the need to examine engagement in specific contexts. This study looks at the specific contexts of large undergraduate courses that rely heavily on TAs to support student learning in order to explore the impacts TAs have on student engagement. In addition to studying engagement at an external behavioral level (via participation), this study also considers internally motivated engagement reflected in the attention and effort that students feel they put forth in their studies. Motivational measures have been identified as having strong associations with self-regulated learning behaviors and learning outcomes (Connell & Wellborn, 1991; Deci et al., 1991) and are as important as time-on-task measures such as participation.

Conceptual Framework

Our investigation of TA contributions to student engagement is informed by multiple models of student and teaching success in higher education. Tinto's (1993) model of student persistence frames student outcomes as arising out of a dynamic interplay between personal and institutional characteristics (Tinto, 1986) and involving both students' academic and social integration with the institution. Previous studies building on Tinto's work have underscored the important contributions that instructors make to student integration (Wolf-Wendel et al., 2009). As instructors, TAs are likely to contribute to students' academic integraiton. Further, since TAs are viewed as more interactive and relatable than regular faculty (Kendall & Schussler, 2012), they are also likely to play a stronger role in students' social integration than regular faculty. While integration is a distinct construct, it has been strongly related to engagement on multiple levels (Kamphorst et al., 2015). Engagement is also impacted by student demographics such as gender and race/ethnicity and incoming student characteristics such as socioeconomic status and parents' education. Astin's Inputs-Environments-Outcomes model assesses how these demographics interact with institutional practices including faculty-student interactions and faculty support in influencing behavioral, psychological, affective, and cognitive outcomes including student engagement. And while the instructional practices that students value share common elements of good teaching, some forms of support vary between disciplines. Therefore, to study TA support in engineering, we two of these common elements: (a) frequent student-teacher contact and (b) prompt feedback (Chickering & Gamzon, 1987) and also practices that are especially important to engineering and other physical sciences. These discipline-specific practices include establishing the relevance of course material through the use of real-world examples and the formulation of clear, objective, and organized instructional goals (Felder, 2000).

Research Questions

Our research sought to understand how *TA support* and *TA-student interactions* are related to student engagement in engineering courses. Two research questions guided our analysis:

Research Question #1 (RQ1):

Are TA Support and TA-student interactions significantly related to student engagement? Previous studies of how TAs influence student engagement in STEM including engineering have been largely limited to laboratory sections and observable measures of engagement. This study adds to that work by exploring multiple learning environments in which TAs operate (e.g. recitations, discussion sections, labs) and digging deeper into student engagement by using student self-reports of an observable measure of engagement (*participation*) and two motivational measures of engagement (*attention* and *effort*).

Research Question #2 (RQ2):

Do different students appear to respond to TA support and TA-student interactions differently? Prior research has shown that instructor support can impact different groups of students in distinct ways and that this holds true for engineering and other STEM undergraduate settings (Hurtado et al., 2011; Seymour & Hewitt, 2000). This study expands on this notion by evaluating which demographic variables interact with *TA support* or *TA-student interactions* in relation to the three forms engagement studied here.

Research Methods

This study is based on a survey that was specifically designed to measure *TA support*, *TA-student interactions*, and student engagement. The study was conducted at a single large public university classified as a doctoral university with very high research activity (Carnegie Foundation, 2018). Class enrollment in the courses surveyed ranged from 60 to 250 students. Multiple TAs supported each course. Most TAs were graduate students, but some were undergraduate students. The majority of TAs were Asian, and most were male. In addition to standard background variables of race and gender, student demographic questions related to socioeconomic status, including family income, mother's education, father's education, and socioeconomic class, were also collected. Due to small sample sizes, minority racial groups were consolidated into two groups: Black and other (non-Black) under-represented minorities (URM). The latter group included Pacific Islander, American Indian, Alaska Native, and other racial groups that were not Asian, Black, or White. The largest populations of students in the sample population were male (74.9%), Asian (45.7%), mid-income (40.3%), domestic (81.0%), or native, non-transfer (72.7%). Detailed demographics describing the survey population are summarized in Table 1.

Table 1: Survey Participant Demographics (*N* = 781)

Demographic	***Group:*** **N (%)***		
Gender	Males: 585 (74.9%)	Females: 184 (23.6%)	
Race	Asian: 357 (45.7%) Black: 27 (3.5%)	Caucasian/White: 311 (39.8%) Other (non-Black) URM: 67 (8.6%)	
Family Income	Low Income (<$40k/yr): 142 (18.2%)	Mid Income ($40k-$100k/yr): 315 (40.3%)	High Income (>$100k/yr): 259 (33.2%)
Mother's Education	No Degree: 189 (24.2%)	AA, AS, BS, BA Degree: 391 (50.1%)	Graduate Degree: 185 (23.7%)
U.S. Status	U.S. Citizen/ Permanent Resident: 633 (81.0%)	International Student: 137 (17.5%)	
Delay to Entry	Native (Non-Transfer): 568 (72.7%)	Transfer: 195 (25.0%)	

* Percentages within a demographic group may not add up to 100% because not all participants responded.

Procedures

Students from seven different sophomore-level engineering courses (four in electrical and computer engineering, three in mechanical engineering) were recruited between Fall 2016 and Spring 2018 to complete a survey about the course in which they were enrolled. The instructor for each course was given the choice of offering the survey to students in paper-and-pencil or electronic form. Students in one course were offered the paper-and-pencil version and completed this version in class. Students in the other six courses were offered the electronic version and completed it outside of class.

Participation in the study was voluntary. Student consent was obtained for all survey participants. At the discretion of the instructor, students were offered an incentive for completing the survey, which was usually a form of extra credit in the course. 781 students completed the survey, representing 85% of students enrolled overall in the seven courses and between 30% and 91% of students in each course, with no duplications (i.e. no student was enrolled in more than one of the courses studied).

Preliminary analyses demonstrated significant bivariate Pearson correlations (greater than 0.6) between mother's education and father's education. Further, preliminary one-way analyses of variance (ANOVA) demonstrated significant differences in engagement ($p < 0.05$) among groups by mother's education, but not by father's education. Therefore, only mother's education was retained for the regression models. Because family income and socioeconomic class had a bivariate Pearson correlation of 0.6, socioeconomic status was also discarded from the regression models while family income level was retained.

U.S. and transfer status were also included in the regression models based on Tinto's model of student integration (Tinto, 1993) which indicates that students' past educational experiences lead to differences in student integration into higher education institutions. Transferring from a community college, working for a significant period of time between high school and university, and attending high school in another country represent major differences in students' past educational experiences compared with students who transition directly from a U.S. high school into university. Thus, they are likely to influence how, when, and why students engage differently than majority populations of students.

Measures

The dependent variables used in this analysis were based on three forms of engagement: *attention*, *effort*, and *participation*. All engagement scales used items that were adapted for use in higher education (Wilson et al., 2015) from previous studies in K-12 (Miserandino, 1996). All engagement items were assessed using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The original scales measuring the three forms of engagement have demonstrated adequate internal consistency and construct validity. Sample items for each engagement scale are provided in Table 2.

Table 2: Engagement (Dependent) Variables

Primary Scale	*Sample Item*
Attention (α = 0.83)	When I'm in this class, my mind wanders.
Effort (α = 0.78)	I try hard to do well in this class.
Participation (α = 0.64)	In this class, I participate in class discussions during lecture with my classmates and instructors.

Attention measures to what extent students are thinking about other things besides the topics at hand in their classes. *Effort* evaluates how hard students try to work in their classes and lab/study groups. *Participation* measures how students view their participation in class discussions. Although in this dataset, *participation* had an internal reliability of less than the standard 0.7, there is evidence that reliability between 0.6 and 0.7 is adequate (George & Mallery, 2010). Therefore, *participation* was retained for analysis.

Two independent variables emerged from this study based on an exploratory factor analysis of 21 items (Table 3) that were either adapted from previous studies of faculty support and faculty-student interactions or observations of TA-led classrooms in engineering. These 21 items included four items adapted from teaching practices in the National Survey of Student Engagement (2019), five items adapted from the teacher academic support subscale developed by Van Ryzin et. al. (2009), and six items adapted from the faculty contact scale used by Einarson and Clarkberg (2010). An additional six items were also formulated based on observations of TA-led classrooms and interactions with students in a previous study (Wright et al., 2019).

Table 3: TA Items

Adapted from	*Label*	*Item*
Teaching Practices	TP1.1	At least one of the TAs or secondary instructors in this class has clearly explained course goals and requirements.
	TP1.2	At least one of the TAs or secondary instructors in this class often teaches in an organized way.
	TP1.3	At least one of the TAs or secondary instructors in this class often uses real-world examples or illustrations to explain difficult points.
	TP1.4	At least one of the TAs or secondary instructors in this class has often provided feedback on a draft or work/homework in progress.
Academic Support	AS1.1	At least one of the TAs or secondary instructors in this class is willing to spend time outside of class to discuss issues that are of interest and importance to me.
	AS1.2	At least one of the TAs or secondary instructors in this class is interested in helping me learn.
	AS1.3	At least one of the TAs or secondary instructors in this class cares about how much I learn.
	AS1.4	At least one of the TAs (or secondary instructors) in this class treats me with respect.
	AS1.5	At least one of the TAs (or secondary instructors) in this class is available when I need help.
Faculty Contact	FC1.1	I have discussed career plans with at least one of the TAs or secondary instructors in this class.
	FC1.2	I have discussed academic work with at least one of the TAs or secondary instructors in this class.
	FC1.3	I have had intellectual discussions outside of academic work with at least one of the TAs or secondary instructors in this class.
	FC1.4	I have discussed course selection with at least one of the TAs or secondary instructors in this class.
	FC1.5	I have socialized with at least one of the TAs or secondary instructors in this class.
	FC1.6	I have discussed my academic performance with at least one of the TAs or secondary instructors in this class.
TA Observations	Obs1.1	The TA for my <recitation or lab> section in this class often arrives at least five minutes before section begins.
	Obs1.2	The TA for my <recitation or lab > section in this class often stays after class to answer questions.
	Obs1.3	The TA for my < recitation or lab > section in this class often stops to ask questions during section.
	Obs1.4	The TA for my < recitation or lab > section in this class is often funny or interesting.
	Obs1.5	I have attended office hours to see at least one of the TAs or secondary instructors in this class.
	Obs1.6	I have e-mailed at least one of the TAs or secondary instructors in this class for assistance.

Data Analysis

Student survey data were analyzed using SPSS 19 to perform preliminary analyses, conduct exploratory factor analyses of the TA items to identify suitable independent variables, and to construct the hierarchical linear regression models that were used to examine the two research quesitons in this study.

Preliminary analyses computed descriptive statistics, evaluated skewness and kurtosis of the engagement variables, computed the reliability of the TA scales, conducted preliminary analyses of variance (ANOVA), computed Pearson bivariate correlations, and constructed null mixed (hierarchical linear or HLM) models. Skewness and kurtosis of the engagement variables were computed to confirm variable normality. Results indicated that all three engagement variables were sufficiently normally distributed to proceed with analysis (George & Mallery, 2010). Pearson bivariate correlations between pairs of engagement variables were all below .5. Therefore, all three engagement variables were retained.

To identify appropriate TA support and TA-student interactions scales, an exploratory factor analysis (EFA) was conducted using varimax rotation. The number of factors was initially determined by an eigenvalue threshold of 1 while also considering the point at which the scree plot for the eigenvalues levelled off and adding additional factors no longer explained variance in the data. Items that demonstrated communalities of less than 0.5 *and* failed to demonstrate a strong (>0.6) loading on any single factor were discarded. Items that loaded onto more than one factor (>0.4) were also discarded. After items were discarded, any remaining factors containing at least two items were retained for analysis.

Using the TA support and TA-student interaction scales that emerged from EFA, a mixed model using HLM (hierarchical linear modelling) was constructed to understand whether nesting of students within TA sections and within courses affected the engagement variables. The results of a null HLM model (i.e. one that did not contain the independent variables) confirmed that the variance contributed to both forms of engagement at the TA level and course level was not significant. Thus, the results of hierarchical regression were unlikely to be confounded by nesting effects, making this approach to data analysis appropriate for this data.

After these preliminary analyses, a series of hierarchical regression models were used to examine the degree to which demographics, TA support, and TA-student interactions predicted the three forms of engagement. TA support and TA-student interactions were all standardized prior to inserting them into the models in order to reduce multicollinearity when interaction terms were introduced. Preliminary regression models using demographic characteristics and the TA behavior scales were used to identify potential interactions of interest. Demographic characteristics were effect coded in the regression models as follows:

- Gender (male = -1; female = 1): other genders were present in very small numbers and were eliminated from the analysis.
- Race (White or Asian = -1 -1; Black = 1 0; other URM = 0 1): the two variables used to represent race were labeled race (Black) and race (non-Black URM).

- Family income (between \$20,000/year and \$80,000/year = -1 -1; less than \$20,000/yr = 0 1; more than \$80,000/yr = 1 0): the two variables used to represent family income were labelled family income (high) and family income (low).

- Mother's education (AA, AS, BS, or BA = -1 -1; a graduate degree (e.g. MS, PhD, JD) = 0 1; no degree = 1 0): the two variables used to represent family income were labelled mother (no degree) and mother (grad degree).

- U.S. citizenship (U.S. citizen or permanent resident = -1; international student = 1): this variable was labelled U.S. status.

- Transfer students (native or non-transfer = -1; transfer = 1): students who began college at the institution in this study at the same time as beginning college altogether were coded as non-transfer. All other students were designated transfer.

Initially, each model considered all possible interactions between the demographic variables and the TA behavior scales. The model was then reduced by eliminating the interaction with the highest *p*-value, one interaction at a time until only significant interactions remained. The Bayesian (BIC) criterion was also calculated and considered in selecting the most parsimonious model for analysis. A reduced model that included significant interactions but also resulted in the lowest BIC was retained for interpretation.

Results

The results of the EFA of the 21 TA iterms are summarized in Table 4. Three factors with eigenvalues greater than 1 emerged from the EFA of these items, but only two factors contained items with loadings and cross-loadings sufficient to retain the factors for analysis. The first factor included a combination of the teaching practices, academic support, and observations of TA teaching practice and was labelled *TA support.* This scale was retained for subsequent analyses and demonstrated a reliability (Cronbach's alpha) of 0.921. It is noteworthy that items related to what the TA was doing (e.g. being organized, asking questions) and what the students perceived the TA felt about what they were doing (e.g. cared and was interested in helping the students learn) loaded onto the same factor.

For the second factor, four of the original six items from the faculty contact scale had loadings of greater than 0.8 onto Factor 2 but did not load onto any other factors. One observation item (Obs 1.6) which asked students to report how often they had contacted a TA by e-mail for assistance also loaded cleanly onto Factor 2. Thus, these five items were retained into a single scale called *TA-student interactions* with a reliability (Cronbach's alpha) of 0.924.

Table 4: Factor Loadings for TA Support Items

Item	Factor 1	Factor 2	Factor 3	Communality	TA Behavior Measure
TP 1.1	**0.744**	0.128	-0.016	0.561	*TA support*
TP 1.2	**0.816**	0.096	0.103	0.687	
TP 1.3	**0.638**	0.214	0.026	0.445	
TP 1.4	**0.640**	0.059	0.254	0.472	
AS 1.1	**0.735**	0.139	0.172	0.561	
AS 1.2	**0.795**	0.126	0.169	0.687	
AS 1.3	**0.790**	0.135	0.155	0.666	
AS 1.4	**0.745**	-0.038	0.225	0.608	
AS 1.5	**0.610**	-0.005	0.235	0.428	
FC 1.1	0.104	**0.880**	0.139	0.807	*TA-student interactions*
FC 1.2	0.162	0.521	**0.584**	0.639	*discarded*
FC 1.3	0.164	**0.857**	0.117	0.775	*TA-student interactions*
FC 1.4	0.113	**0.858**	0.132	0.766	
FC 1.5	0.280	0.429	**0.617**	0.643	*discarded*
FC 1.6	0.102	**0.845**	0.223	0.773	*TA-student interactions*
Obs 1.1	**0.611**	0.094	-0.151	0.405	*TA support*
Obs 1.2	**0.703**	0.089	0.064	0.507	
Obs 1.3	**0.682**	0.180	-0.042	0.500	
Obs 1.4	**0.749**	0.244	0.111	0.632	
Obs 1.5	0.093	0.322	**0.805**	0.760	*discarded*
Obs 1.6	0.102	**0.845**	0.223	0.545	*TA-student interactions*

Descriptive statistics for *TA support* and *TA-student interactions* as well as the three engagement measures (*attention*, *effort*, *participation*) are summarized in Table 5. All measures were scaled to values between 1 and 5.

Table 5: Descriptive Statistics

	TA support	*TA-student interactions*	*Attention*	*Effort*	*Participation*
N	696	755	762	765	736
Mean	3.56	1.58	2.76	3.88	3.21
Standard Deviation	0.78	0.87	0.99	0.79	0.95
Maximum	5.00	5.00	5.00	5.00	5.00
Minimum	1.08	1.00	1.00	1.00	1.00

Engagement Models

A three-level regression model was constructed for each engagement variable. Model 1 contained all nine demographic variables, effect coded as described previously. Model 2 contained *TA support* and *TA-student interactions*, and Model 3 contained interactions that were associated with the most parsimonious regression model for each form of engagement.

Table 6: Summary of Linear Regression Models for Engagement

	Model 1	Model 2	Model 3
Attention	$R^2 = 0.036$ $\Delta R^2 = 0.042$ Adjusted $R^2 = 0.042$ SE = 0.972 $\Delta F = 2.30$*	$R^2 = 0.072$ $\Delta R^2 = 0.036$ Adjusted $R^2 = 0.053$ SE = 0.956 $\Delta F = 10.6$***	$R^2 = 0.111$ $\Delta R^2 = 0.040$ Adjusted $R^2 = 0.089$ SE = 0.938 $\Delta F = 8.18$***
	Interactions: gender X TA support; race(black) X TA support; U.S. status X TA-student interactions		
Effort	$R^2 = 0.026$ $\Delta R^2 = 0.026$ Adjusted $R^2 = 0.011$ SE = 0.808 $\Delta F = 1.67$	$R^2 = 0.117$ $\Delta R^2 = 0.091$ Adjusted $R^2 = 0.099$ SE = 0.771 $\Delta F = 28.3$***	$R^2 = 0.133$ $\Delta R^2 = 0.016$ Adjusted $R^2 = 0.114$ SE = 0.765 $\Delta F = 10.2$**
	Interactions: U.S. status X TA support		
Participation	$R^2 = 0.050$ $\Delta R^2 = 0.050$ Adjusted $R^2 = 0.035$ SE = 0.952 $\Delta F = 3.28$**	$R^2 = 0.288$ $\Delta R^2 = 0.238$ Adjusted $R^2 = 0.274$ SE = 0.822 $\Delta F = 94.2$***	$R^2 = 0.296$ $\Delta R^2 = 0.008$ Adjusted $R^2 = 0.281$ SE = 0.821 $\Delta F = 6.10$*
	Interactions: mother (no degree) X TA support		
	* $p<0.05$; ** $p < 0.01$; *** $p < 0.001$		

In all three engagement regressions (Table 6), the independent variables (demographic characteristics) used in the first level of each model explained little of the variance in the data (3.6%, 2.6% and 5.0% for *attention*, *effort* and *participation* respectively). Including *TA support* and *TA-student interactions* in Model 2 substantially strengthened each of the models. The two-level models explained 7.2%, 11.7%, and 28.8% of the variance in the data for *attention*, *effort*, and *participation* respectively.

Attention

The regression models for *attention* are summarized in Table 7. Being an international student consistently, significantly, and positively predicted *attention*. No other demographic variables predicted *attention* once *TA support* and *TA-student interactions* were considered (Model 2). Both *TA support* and *TA-student interactions* significantly predicted *attention*. However, the regression coefficient for *TA support* was positive ($p<0.01$) while that for *TA contact* was negative ($p<0.001$).

Only three interactions remained significant in the process of iteratively reducing the model to its most parsimonious form. As a result of the reduction, the BIC decreased to 7.30 (only three interactions considered) from 87.7 when all 18 interactions were considered and 13.0 when no interactions were considered. Interactions between gender and *TA support*, race and *TA support*, and U.S. status and *TA-student interactions* were all significant. The attention reported by women increased more with increasing *TA support* than for men (Figure 1). Attention reported by black students decreased with increasing *TA support* but increased for White and Asian students (Figure 2). And, while *attention* among all students decreased with increasing *TA-student interactions*, the effect was more pronounced for international students than for U.S. citizens and permanent residents (Figure 3).

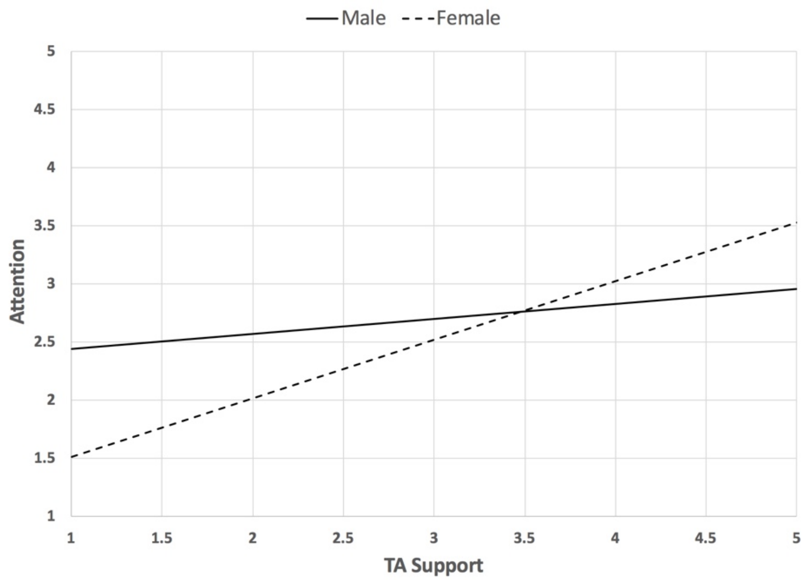

Figure 1: Interactions between Gender and *TA support* for Attention

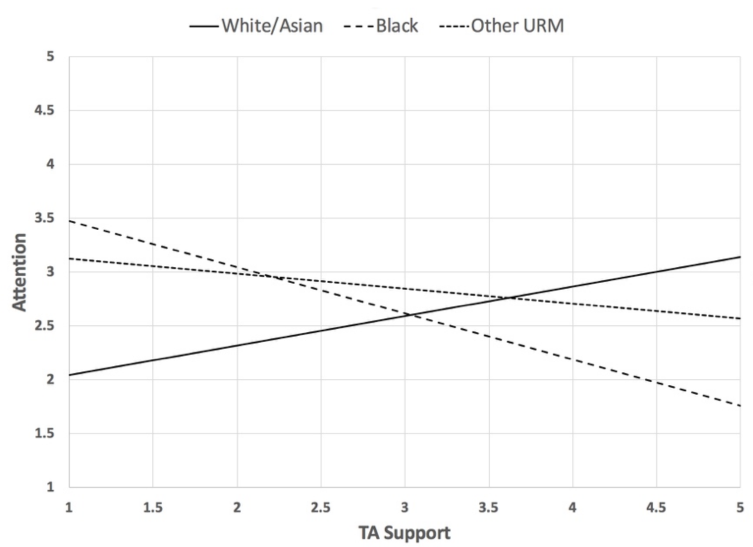

Figure 2: Interactions between Race and *TA support* for Attention

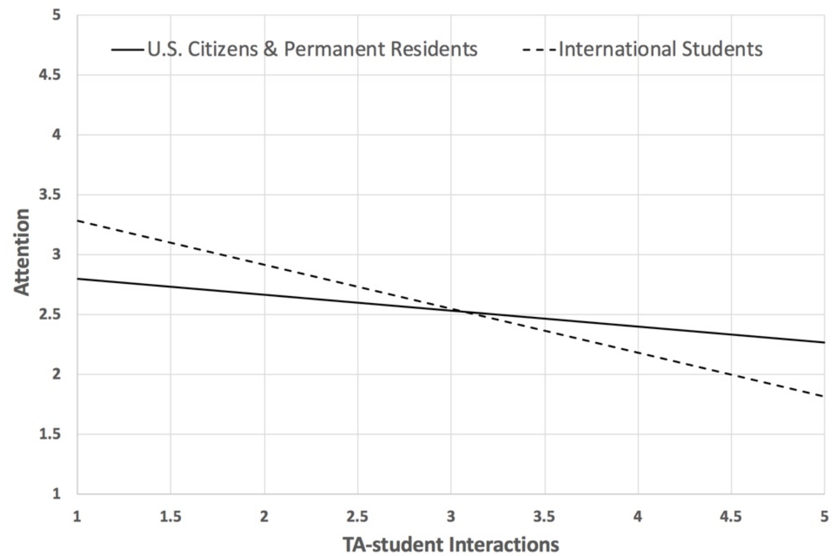

Figure 3: Interactions between U.S. Status and *TA-student interactions* for Attention

Table 7: Hierarchical Regression Models for Attention

Predictor Variable	Level 1			Level 2			Level 3		
	B (SE)	*p*		B (SE)	*p*		B (SE)	*p*	
Constant	2.94 (0.11)	0.000	***	2.58 (0.24)	0.000	***	3.62 (0.50)	0.000	***
Gender	0.00 (0.05)	0.968		-0.01 (0.05)	0.794		-0.00 (0.05)	0.949	
Race (Black)	0.06 (0.17)	0.739		0.08 (0.17)	0.654		0.24 (0.18)	0.176	
Race (other URM)	-0.02 (0.12)	0.867		-0.03 (0.12)	0.807		-0.12 (0.13)	0.359	
Family income (high)	-0.12 (0.06)	0.066		-0.10 (0.06)	0.102		-0.09 (0.06)	0.139	
Family income (low)	-0.01 (0.08)	0.935		-0.01 (0.08)	0.859		-0.03 (0.07)	0.647	
Mother (no degree)	-0.05 (0.07)	0.464		-0.05 (0.07)	0.490		-0.04 (0.07)	0.519	
Mother (grad degree)	0.00 (0.07)	0.962		0.00 (0.07)	0.950		-0.02 (0.07)	0.716	
U.S. status	0.14 (0.06)	0.010	*	0.17 (0.06)	0.004	**	0.20 (0.06)	0.001	**
Transfer status	0.10 (0.05)	0.043	*	0.09 (0.05)	0.066		-0.25 (0.06)	0.076	
TA support				0.19 (0.06)	0.001	**	-0.05 (0.13)	0.718	
TA-student interactions				-0.02 (0.05)	0.000	***	-0.25 (0.06)	0.000	***
Gender X *TA support*							0.12 (0.05)	0.012	*
Race (Black) X *TA support*							-0.29 (0.10)	0.004	**
U.S. status X *TA-student interactions*							-0.14 (0.05)	0.003	**

* p<0.05; ** p < 0.01; *** p < 0.001

Effort

Regression results for *effort* are summarized in Table 8. Being Black or another under-represented racial/ethnic minority student initially predicted *effort* as did being a transfer student. However, the significance of this relationship disappeared when *TA support* and *TA-student interactions* were taken into account. No other demographic variables significantly predicted *effort* in any of the models, but both *TA support* ($p < 0.001$) and *TA-student interactions* ($p < 0.05$) significantly and positively predicted *effort*. The more support from and interactions with TAs that students had, the more effort they put forth.

Only one interaction remained significant in the process of iteratively reducing the model. As a result of the reduction, the BIC decreased to -234 (only one interaction considered) from -138 when all 18 interactions were considered and -229 when no interactions were considered. In the final model, interactions between U.S. status and *TA support* were significant. The association between *effort* and *TA support* was more positive for international students than for U.S. citizens and permanent residents (Figure 4).

Table 8: Hierarchical Regression Models for Effort

Predictor Variable	Level 1			Level 2			Level 3		
	B (SE)	*p*		B (SE)	*p*		B (SE)	*p*	
Constant	3.98 (0.09)	0.000	***	2.74 (0.19)	0.000	***	2.27 (0.24)	0.000	***
Gender	0.01 (0.04)	0.782		0.02 (0.04)	0.588		0.02 (0.04)	0.617	
Race (Black)	0.33 (0.14)	0.023	*	0.23 (0.14)	0.100		0.25 (0.14)	0.076	
Race (other URM)	-0.23 (0.10)	0.024	*	-0.19 (0.10)	0.054		-0.20 (0.10)	0.041	*
Family income (high)	-0.05 (0.05)	0.331		-0.06 (0.05)	0.239		-0.06 (0.05)	0.221	
Family income (low)	0.06 (0.06)	0.382		0.04 (0.06)	0.475		0.05 (0.06)	0.452	
Mother (no degree)	-0.07 (0.06)	0.262		-0.05 (0.06)	0.370		-0.04 (0.06)	0.443	
Mother (grad degree)	0.03 (0.06)	0.588		0.01 (0.05)	0.907		0.01 (0.05)	0.857	
U.S. status	-0.01 (0.05)	0.878		-0.08 (0.05)	0.084		-0.11 (0.05)	0.016	*
Transfer status	0.09 (0.04)	0.029	*	0.04 (0.04)	0.347		0.05 (0.04)	0.220	
TA support				0.28 (0.04)	0.000	***	0.41 (0.06)	0.000	***
TA-student interactions				0.09 (0.04)	0.026	*	0.08 (0.04)	0.066	
U.S. status X TA support							0.15 (0.05)	0.001	**

* p<0.05; ** p < 0.01; *** p < 0.001

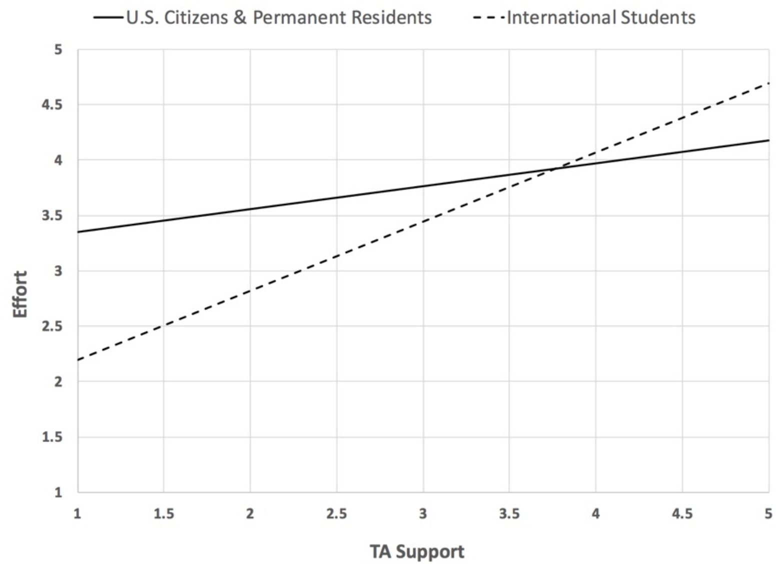

Figure 4: Interactions between U.S. Status and *TA support* for Effort

Participation

Results for the last regression model evaluated *participation*. Results for the reduced model are summarized in Table 9.

Table 9: Hierarchical Regression Models for Participation

Predictor Variable	Level 1			Level 2			Level 3		
	B (SE)	*p*		B (SE)	*p*		B (SE)	*p*	
Constant	3.55 (0.11)	0.000	***	1.12 (0.20)	0.000	***	1.27 (0.21)	0.000	***
Gender	-0.04 (0.05)	0.398		-0.02 (0.04)	0.556		-0.02 (0.04)	0.540	
Race (Black)	0.37 (0.17)	0.031	*	0.18 (0.15)	0.235		0.21 (0.51)	0.169	
Race (other URM)	-0.15 (0.12)	0.231		-0.07 (0.11)	0.505		-0.09 (0.11)	0.388	
Family Income (high)	-0.07 (0.06)	0.254		-0.09 (0.05)	0.089		-0.09 (0.05)	0.081	
Family Income (low)	0.12 (0.08)	0.117		0.10 (0.07)	0.133		0.09 (0.07)	0.157	
Mother (no degree)	-0.13 (0.07)	0.068	*	-0.09 (0.06)	0.124		-0.09 (0.06)	0.113	
Mother (grad degree)	-0.15 (0.07)	0.024		0.10 (0.06)	0.085		0.10 (0.06)	0.086	
U.S. status	0.14 (0.06)	0.011	**	0.00 (0.05)	0.983		-0.01 (0.05)	0.848	
Transfer status	0.11 (0.05)	0.017	*	0.01 (0.04)	0.850		0.01 (0.04)	0.783	
TA support				0.54 (0.05)	0.000	***	0.50 (0.05)	0.000	***
TA-student interactions				0.18 (0.04)	0.000	***	0.17 (0.04)	0.000	**
Mother (no degree) X TA support							-0.11 (0.04)	0.014	*

* p<0.05; ** p < 0.01; *** p < 0.001

In this model, being an international student (U.S. status), being Black and being a transfer student both positively and significantly predicted *participation*, while having a mother with no degree negatively predicted *participation*. However, when *TA support* and *TA-student interactions* were introduced to the model, these effects disappeared. As with the other models (*attention*, *effort*), *TA support* significantly and positively predicted *participation*. And, as was the case with *effort*, *TA-student interactions* also significantly and positively predicted *participation*.

Only one interaction remained significant in the process of iteratively reducing the model. As a result of the reduction, the BIC decreased to -157 (only one interaction considered) from -55 when all 18 interactions were considered. Interactions between mother's education (i.e. mother had no college degree) and *TA support* were significant and the nature of those interactions is shown in greater detail in Figure 5. The *participation* reported by students whose mother had a college degree increased more with increasing *TA support* than for students whose mother had no college degree. Further, students whose mother had a degree but perceived low levels of *TA support* reported less *participation* than their peers whose mother had no degree. However, the opposite was true at higher levels of *TA support* -- students whose mother had a degree reported higher levels of *participation* than those students whose mother did not have a degree.

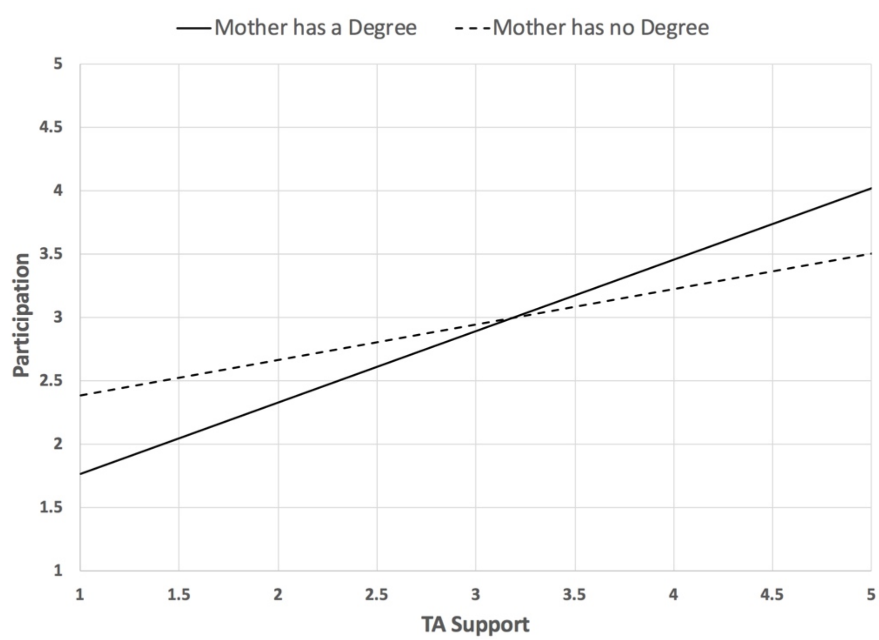

Figure 5: Interactions between Mother's Education and *TA support* for Participation

Discussion

Both *TA support* and *TA-student interactions* were consistently and significantly associated with all three forms of engagement, although the nature of this relationship was not always positive. Interactions with particular demographic groups also emerged and merit further investigation.

Research Question #1 (RQ1):

Are TA support and TA-student interactions significantly related to student engagement?

The regression results suggested that much of what TAs do is strongly connected to engagement among all students, regardless of demographics. Both *TA support* and *TA-student interactions* were significantly associated with all three forms of engagement. With the exception of *attention* and *TA-student interactions*, all of these relationships were significant and positive. And, the relationships between *TA support* and the three engagement measures were consistently stronger than those for *TA-student interactions*.

The significant and positive associations between *TA support* and engagement indicated that students who paid more attention, participated more, and put forth more effort overall in both lecture and lab/discussion sections felt that their TA was organized, used good examples, engaged students during class, and demonstrated care and interest in student learning. Consistent with Umbach & Wawryzynski's (2005) study of faculty support and engagement among over 40,000 undergraduates, these results suggest that these course-related TA behaviors play an important role in student engagement across the board. In Umbach & Wawryzynski's study, course-related interactions with faculty and faculty support for learning were significantly related to engagement as measured by time on task and investment in certain academic activities such as hours spent preparing for class and number of papers written. In this study, the relationships between instructor support and student engagement extended to TA practices as well, thereby demonstrating the importance of all instructors in making meaningful contributions to student engagement.

TA-student interactions were also significantly associated with all three forms of engagement. As with *TA support*, these findings mirror other studies of faculty contributions to engagement that illustrated the importance of quality faculty-student interaction (Bjorklund et al., 2004; Chen et al., 2008; Heller et al., 2010). Indeed, given that students in engineering and other STEM courses were often more likely to have direct contact with a TA than with a faculty member (Gardner & Jones, 2011; Rushin et al., 1997) and that students expected their TA to be approachable and accessible (Kendall & Schussler, 2012), this finding is especially relevant for understanding engagement in this setting.

Despite the importance of *TA-student interactions* in the regression models, the relationships between *TA-student interactions* and *attention* (B = -0.02), *effort* (B = 0.09), and *participation* (B = 0.18) were not as strong as for *TA support* and *attention* (B = 0.19), *effort* (B = 0.28), and *participation* (B = 0.54). The *TA-student interactions* scale in this study included both course-related interactions and interactions unrelated to the course. In contrast, the *TA support* measure included only course-related measures. Umbach & Wawryzynski's study (2005) also found that among faculty, out-of-class interactions with faculty had less of an effect on student engagement than within-class interactions and practices, which reinforces the similarities between how interactions with faculty and TAs impact student engagement.

Interestingly, although *TA-student interactions* positively predicted *effort* and *participation,* these interactions negatively and significantly predicted *attention*. In other words, students who reported higher levels of contact with their TA also tended to report lower levels of in-class *attention*. Closer examination of this relationship (Figure 6) suggests that this negative effect is most evident among students who have frequent interactions with TAs.

It is possible that some students may seek out interaction with their TAs because they are interested and engaged, while others seek out interaction because they are struggling with course material, which could be a cause or result of decreased *attention* in class. Indeed, another study of engineering and other STEM students identified a similar issue with student-instructor interaction patterns, finding that students who were struggling academically or who had received negative feedback from faculty about their work reported more frequent interaction with their professors (Hurtado et al., 2011). It stands to reason that students who are struggling academically may find it difficult to keep up and pay attention in class and may turn to interactions with instructors, especially TAs, outside of class to compensate.

The results of this study support that *TA support* and *TA-student interactions* are closely associated with student engagement. While these results held true for all students, regardless of demographics, our models also showed that some relationships between *TA support* and *TA-student interactions* and student engagement measures played out in unique ways for particular groups of students. These findings are discussed next.

Research Question #2 (RQ2):

Do different students appear to respond to TA support and TA-student interactions differently?

While some aspects of TA teaching clearly matter for all students, our results point toward some variation in these relationships among different student groups. Tinto's (1986) theory supports this, stating that student integration arises from dynamic interplay between individual student characteristics (e.g. gender, race, educational background) and institutional characteristics (e.g. instructor teaching styles). The following section discusses results which were not generalizable to all students but were true for certain demographic groups.

Gender: *TA support* positively predicted *attention* more strongly for women than for men (Figure 1a), although no significant interactions between gender and *effort* or *participation* emerged from the regression models. As numerical minorities in engineering, female students face a number of potential stressors including but not limited to the experience of stereotype threat (Murphy et al., 2007; Steele, 1997), a lower sense of belonging (Lewis et al., 2017) and lower perceptions of support for question-asking in comparison with male peers (Haskett et al., 2017). As a result of these barriers, women may respond more strongly to TA support than men do. The level of *attention* among women in the present study certainly appears to confirm this hypothesis. Of students who report low levels of *TA support*, women pay less *attention* than men, but of those experiencing high levels of *TA support*, women respond more strongly than men by paying far more *attention*. Strong *TA support* may function as a buffer against the risk women in engineering face with potentially more negative experiences in their courses compared to male peers. Indeed, academic integration – including positive contact with instructors – is highly important for female student academic success in engineering (Kamphorst et al., 2015). The present study extends this relationship to include the influence of TAs as well as faculty.

International Students: *TA-student interactions* negatively predicted *attention*, and more so for international students than for U.S. citizens and permanent residents (Figure 3). International students often experienced feelings of inferiority in their primary classrooms due to their English language ability (J. Kim, 2012) and perceived that American faculty think less of them than their American peers (Valdez, 2015). Furthermore, international students and non-White students had more positive views of international teaching assistants (Neves & Sanyal, 1991) than White, U.S.-born students did. In this study, a large majority of the international students were Asian, a majority of faculty were White and U.S. citizens, and a majority of TAs were Asian, many of them international. It stands to reason, then, that international students who struggled in the classroom to be accepted and understand what a professor is saying may turn to international TAs from similar Asian cultures to compensate for reduced ability or desire to pay *attention* in the primary classroom. When such TAs are perceived as more supportive, these students were also likely to put forth more *effort* (Figure 4).

Race: Interestingly, Black students paid less *attention* when they report greater *TA support* (Figure 2); other under-represented minority students also exhibited this trend, although the interaction is not statistically significant in the regression models. In a large, quantitative study of undergraduates at 10 University of California campuses, Kim & Lundberg (2016) found that the benefits of faculty-student interaction for outcomes including classroom engagement, cognitive gains and sense of belonging were moderated by race/ethnicity, with minority students experiencing lower levels of faculty-student interaction and reaping fewer of the benefits thereof. Our findings should be interpreted with some caution given the small number of Black students in the sample (3.5% of the total sample size), but these findings suggest that similar to international students, Black students may be compensating for perceived disparities in the classroom and lower support from faculty by turning to TAs when strong *TA support* is available. Alternatively, when strong *TA support* is available, these students may be finding less need to pay *attention*.

Mother's Education: The results of this study found that *TA support* more strongly predicted *participation* for students whose mother had a college degree compared to those students whose mother did not (Figure 5). Given the high correlation between the mother's education and father's education among participants in this study (Pearson's correlation = 0.608, $p < 0.01$), it is reasonable to presume that most students who reported their mother having no college degree were first-generation college students (i.e. neither mother or father had a college degree). The weaker relationship between *TA support* and *participation* for first-generation students is consistent with the mismatch between the norms of independence of the American university and the norms of interdependence that dominate the working class (Stephens et al., 2012) which limit the benefits first-generation students can reap from both faculty and TAs. Other research has also established that first-generation students have lower academic engagement than continuing-generation students as measured by student-faculty interactions and participation in class than their continuing-generation peers (Soria & Stebleton, 2012). However, in this study, students whose mothers had no degree report higher levels of engagement (as measured by *participation*) than continuing-generation students when they perceive that *TA support* is low. A possible explanation for this anomalous result may be that since first-generation students are less integrated academically and struggle to fit in given their relative lack of culture capital (Spengen, 2013), they may be less responsive than their peers to anomalous levels of instructional support. This possibility merits further study.

Limitations and Implications

Limitations: This study was limited to seven engineering courses at a single institution. Thus, we cannot claim that our findings are generalizable to other engineering courses at other institutions. But, evaluated in the context of the broader research on engagement and instructional support, our study reinforces the importance of the TA in the student's life and offers insight into how TA behaviors may be perceived and processed differently from faculty support. Another limitation of this study is that the collected data are cross-sectional in nature and cannot prove cause and effect. However, an argument can be made that, within a single term and course, what TAs do is more likely to influence student engagement than student engagement is to influence what TAs do.

Implications: This study has reinforced the notion that TAs have tremendous potential to improve student engagement in undergraduate engineering courses. Whether this potential is realized depends on the degree to which TAs are equipped with pedagogical tools for promoting engagement among their students. Gaining a greater understanding of the types of support that TAs offer to students and how such support is related to student engagement and other outcomes is essential for developing effective and efficient professional development and training for these novice teachers. This study reinforces the need for strong TA professional development as well as implementing course- and department-level practices which influence the degree to which TAs are supported in their teaching roles.

Concluding Remarks

This study underscores the importance of TAs in the engineering classroom, both in the support they provide and the interactions they have with students. In combination with other related studies, the results presented here support the fact that institutions seeking to enhance student engagement should approach the task with the assumption that teaching is not a one-size-fits-all endeavor. Strategies that reach one audience may not reach all. Demographics matter. Therefore, TAs should be equipped with tools for "temperature checks" in their classes (e.g. midterm evaluations, periodic student reflections) to identify when the engagement needs of some students may be going unmet. This, coupled with a more robust, varied toolkit of engagement strategies, may enable TAs to bolster the engagement of all students at multiple levels.

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