

Influence of Team Skills in Engineering Technology

Full Paper

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Abstract

Across various disciplines, self-efficacy, team-working skills and problem solving skills are recognized as important characteristics of workforce readiness. The purpose of this research is to examine the impact of multiple antecedents of perceived team-working skills and self-efficacy on change in team scores and higher-order cognitive skills when all students are provided the same treatment. The study involves the use of a multimedia instructional environment and problem-based learning in teams. Data were collected at multiple points during the semester using a combination of self-reported instruments and grades provided by instructors. We found that students' institution, gender, and perceived relevance of engineering technology contribute to perceived team skills. Surprisingly, and in contrast to extant self-efficacy literature, self-efficacy is not related to perceived higher order cognitive skills or actual performance. However, perceived team skills were an accurate predictor of perceived higher order cognitive skills and actual team scores.

Keywords

Self-efficacy, team-working, instructional environment, multimedia

Introduction

Across various disciplines, self-efficacy, team-working skills and problem solving skills are recognized as important characteristics of workforce readiness. Both business and engineering researchers have begun to emphasize the importance of knowledge, skills, and attitudes associated with teamwork and interpersonal skills (Kalliath and Laiken 2006; Verzat et al. 2009). One reason for an increased emphasis on these skills is that many graduates are entering the job market with sufficient levels of technical proficiency but insufficient interpersonal skills (Goltz et al. 2008; Halfhill and Nielsen 2007). Further, accrediting bodies such as the Association to Advance Collegiate Schools of Business (AACSB) and the Accreditation Board for Engineering and Technology (ABET, Inc.) have called for improved interpersonal and team-skills in both business and engineering technology graduates (AACSB 2007; ABET 2008).

What remains largely unclear in the literature is the effect of pre-existing characteristics of undergraduate students that act as antecedents to acquiring team-skills and improving self-efficacy. Characteristics that exist prior to engagement in learning have been referred to as presage factors (Biggs and Moore 1993; Cybinski and Selvanathan 2005; Nemanich et al. 2009), and have been shown to produce varying levels of influence on the learning process. Throughout this study, an emphasis is placed on the influence of presage factors on the learning process and, ultimately, learning products (i.e., performance).

Although some benefits of an increased focus on team-based learning are evident in classrooms dominated by Caucasian males, further research is necessary to examine the benefits afforded to non-majority members in both business and engineering technology classrooms (i.e., women and racial minorities). Additionally, research suggests that differences are prevalent in the self-efficacy of engineering technology students across gender (Marra et al. 2009; Zeldin and Pajares 2000).

The purpose of this research is to examine the impact of multiple antecedents of perceived team-working skills and self-efficacy on change in team scores and higher-order cognitive skills when all students are provided the same treatment. The study involves the use of a multimedia instructional environment and problem-based learning in teams. Additionally, two distinct institutions provide the sample for this study. The results of this study are expected to explain how differences among students can lead to higher perceptions of team working skills and engineering self-efficacy, as they affect student performance. In the next section, our model is defined and a literature review provides support for the hypothesized relationships. The evaluative method used to test our framework is then introduced, along with analysis and key findings. The paper concludes with a discussion of the limitations and areas for future research.

Model and Hypotheses

We use the presage, process, and product (3P) model (Biggs and Telfer 1987; Cybinski and Selvanathan 2005; Nemanich et al. 2009) to examine whether presage factors are associated with higher perceptions and, ultimately, higher levels of academic performance. Nemanich et al. (2009) define the 3Ps in the following manner: *presage* encompasses characteristics that exist prior to engagement in learning, *process* incorporates the students' learning experience, and *product* represents the students' learning outcomes. Cybinski and Selvanatham (2005) further clarify these factors: *presage* factors can consist of student variables such as knowledge, personality, or background, *process* factors focus on the student's perceptions of the learning environment that influence choices regarding a specific learning strategy or motivation, and *product* factors can consist of exam results, satisfaction, or grade point average.

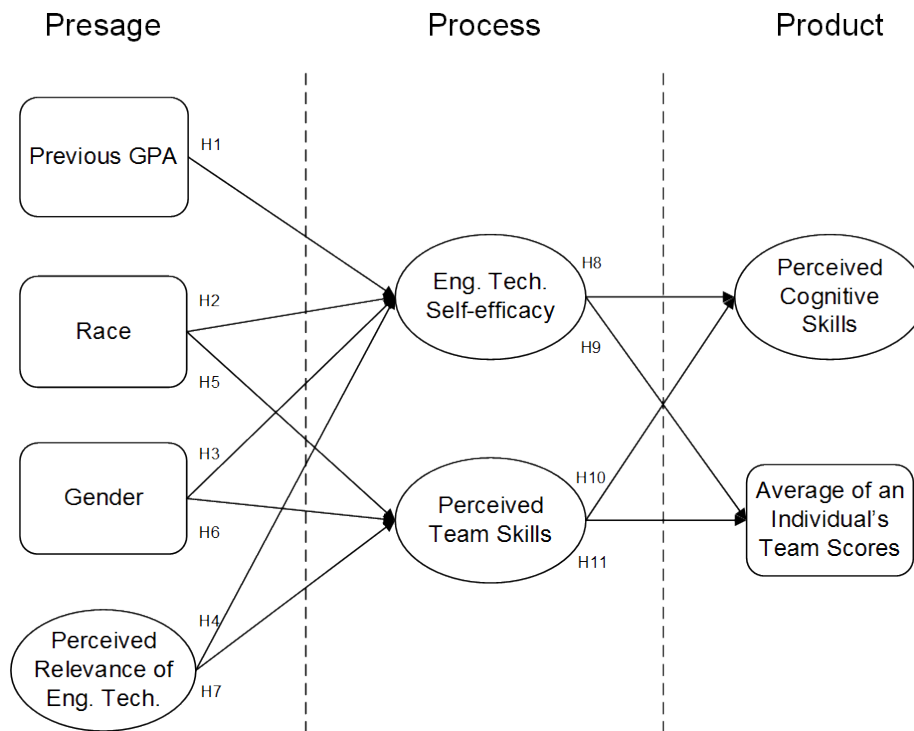


Figure 1. Research model showing the hypotheses tested

Presage factors as antecedents to process factors

Our research model seeks to contribute to the 3P literature by examining the relationships between additional presage and process factors. Figure 1 displays the key relationships in this study among the presage, process, and product factors. Previous GPA serves as a proxy for a student's knowledge and abilities prior to the study, gender is used to distinguish between male and female students, and perceived relevance

of engineering technology is tied to a student's motivation to succeed in the area of study, a key presage condition. In our sample, the two institutions had student populations that were clearly delineated based on race. Historically Black Colleges and Universities (HBCU) are common throughout the United States and are predominantly comprised of African-American students, making them an appropriate sample for this study. For this reason we used institution (i.e., HBCU and non-HBCU) as a proxy for race (African-American and Caucasian).

Self-efficacy. Bandura (1997, p. 3) defined self-efficacy as "belief in one's capability to organize and execute the courses of action required to produce given attainments." Extant literature has found self-efficacy to be a reliable predictor of academic performance, both across disciplines (Zajacova et al. 2005), and in Science, Technology, Engineering, and Math (STEM) education (Lent et al. 1984). Bandura (1997) theorized that general self-efficacy emerges from four sources. The most influential source, a key component of the current study, is one's enactive mastery experiences. Bandura explained that enactive mastery experiences act as reference points throughout an individual's educational career to determine their propensity to succeed in the face of obstacles. Specifically, the perceived success of a task should increase a person's self-efficacy, while the perceived failure of a task should decrease that person's self-efficacy. Therefore, we expect to find a similar relationship in the current study. We hypothesize that GPA is positively related to students' perceptions of their capabilities (i.e., self-efficacy).

H1: Previous GPA is positively related to engineering technology self-efficacy.

As noted by Chubin (2005), in order to meet the United States' increasing need for world-class STEM talent, we must also consider a pool of graduates that looks different from decades past. However, with regard to race, studies have found that African-American students have historically held culturally unfavorable views of STEM professions (Powell 1990). Further, Flowers and Pascarella (2003) suggest that the accumulated research shows that African-American students are more likely to perceive the college environment as unwelcoming and hostile. It is possible that a student's perceptions of college and, specifically, engineering technology will influence their perceptions regarding their own abilities to perform in that discipline. Therefore, we hypothesize that a difference exists with regard to a student's race and their level of engineering technology self-efficacy.

H2: Engineering technology self-efficacy will be higher for Caucasians students than African-American students.

As noted previously, gender has shown to be a dividing presage factor with regard to student perceptions, especially in STEM disciplines. Zeldin and Pajares (2000) suggest that low levels of self-efficacy, even in women who are competent, have led some women to avoid mathematics-related careers. Additional research suggests that a confidence gap exists between men and women in their beliefs that they can succeed in math and science (Sadker and Sadker 1994). Because engineering relies on a strong math and science background, we proffer that differences in perceptions between males and females will also exist in engineering technology courses. Therefore, we hypothesize a difference in the relationship of gender and engineering technology self-efficacy.

H3: Engineering technology self-efficacy will be higher for male students than female students.

Finally, Nemanich et al. (2009) found that perceived content relevance was related to student enjoyment and understanding (i.e., process factors). Additionally, Cybinski and Selvanathan (2005) found that the perceived importance or value of statistics (i.e., presage) displayed a significant positive relationship with enjoyment of statistics (i.e., process). Therefore, we hypothesize a relationship between perceived relevance of engineering technology (i.e., presage) and the improvement in a student's self-efficacy (i.e., process).

H4: A student's perceived relevance of engineering technology is positively related to his or her engineering technology self-efficacy.

Perceived Team-skills. A study by Sinclair (1997) asked business representatives and university educators to rank their desired characteristics of college graduates and found that business representatives ranked teamwork-related characteristics much higher than did university educators. The disparity in these results is important because it illuminates the gap between the perspectives of academia and industry, potentially impacting the workforce readiness of graduates. Seat et al. (2001) referred to team skills as one of the performance skills "of concern to both industry employers and engineering educators." Felder et al.

(2000) and Verzat et al. (2009) suggest that more engineering work is done cooperatively than individually, requiring sufficient levels of interpersonal skills. Fortunately, a growing number of administrators and academics are collaborating to produce graduates with the skills needed to perform in a team environment. In order to contribute to this task, we seek to advance the field of team-based learning and team performance by examining the antecedents of perceived team-skills and the relationship between those perceptions and actual performance.

When considering the various presage factors that could influence perceived team-skills, we consider race and gender increasingly important. The value of race and gender in organizations is evidenced by the increase in ideas and innovativeness associated with diversity and multiculturalism in today's global business environment. As Chubin et al. (2005) note, diversity is better thought of as an asset that makes teams more creative and products more usable. Because some have suggested that engineering technology currently suffers from a diversity problem (Chubin et al. 2005; Davis and Finelli 2007; Noeth et al. 2003), it is important that researchers determine whether race and gender might lead to differences in perceptions and performance. Scherpereel and Bowers (2008) found that females tend to underrate their performance in teams, both before and after they receive feedback about their performance. Therefore, we hypothesize the following relationships.

H5: Perceived team-working skills will be higher for Caucasians than African-Americans.

H6: Perceived team-working skills will be higher for males than females.

Based on their literature review, Nemanich et al. (2009) suggest that students who see material as applicable to themselves will find it more interesting. Further, they suggest that student motivation will likely increase when classroom content is connected to students' current interests and future needs. Following this logic, it is possible that a student's perceptions of a subject (i.e., engineering technology) will influence perceptions of their ability to perform as a member of a group in that particular subject. Thus, we hypothesize the following relationship.

H7: A student's perceived relevance of engineering technology is positively associated with their perceived team-working skills.

Process factors as antecedents to product factors.

Self-efficacy. Numerous studies have found that student self-efficacy is an accurate predictor of academic achievement and choice intentions (Gainor and Lent 1998; Lent et al. 1984; Lent et al. 1986; Multon et al. 1991). We operationalize subjective academic performance as an individual's perception regarding their gain in higher-order cognitive skill level at the conclusion of the team activities. In order to test these relationships, we present the following hypotheses.

H8: Engineering technology self-efficacy is positively associated with perceived higher-order cognitive skills.

H9: Engineering technology self-efficacy is positively associated with team-working scores.

Perceived team-skills. Extant literature discussing team-skills is filled with studies that tout the benefits of team-based learning and its impact on student outcomes, such as academic achievement, favorable attitudes towards learning, and persistence in STEM (Springer et al. 1999). However, there is a paucity of research discussing the relationship between an individual's perception of their team-skills and measures of actual performance. A growing area of the team based learning literature suggests that an individual's participation with a team does not guarantee performance improvements (Prichard, Stratford, & Bizo, 2006), and in fact, could hinder student performance (Bacon, 2005). Additional findings suggest that team-skills training will improve the learning outcomes for students (Bowen, 1998; Prichard, et al., 2006). Considering the conflicting results associated with these arguments, it might be advantageous for those working in higher education to determine which students are in need of training by considering their perceived team-skills, and whether those perceptions relate to performance. In order to measure this link, we present the following hypotheses involving the relationship between perceived team-skills and perceived higher-order cognitive skills, and between team-skills and actual team-working scores.

H10: Perceived team-working skills are positively associated with perceived higher-order cognitive skills.

H11: Perceived team-working skills are positively associated with team-working scores.

Method

Treatment: Multimedia Case Studies

In order to examine individual perceptions of team-skills and team performance, we utilized multimedia instructional materials that required students to work in a team setting. Multimedia instructional materials are any material used for instruction that contains one or more of the following: graphics, video, animation, images, and sound in addition to textual information (Beckman 1996; Fetterman 1997; Mbarika et al. 2003b). As a form of problem-based learning (PBL), multimedia case studies require students to assess actual situations faced by practicing engineers. Multimedia case studies are the specific instructional materials implemented in this study.

We used three case studies in the current research, each of which incorporates real-world technology problems. The first study involves the events leading up to the decision to launch the Challenger space shuttle, STS 51-L, focusing on the technical details that led to the shuttle's explosion. The second case study involves the design of a machine at a textile mill that led to the injury of an employee and the ensuing legal battle. The third case study involves the decision process requirements of Chick-fil-A in their selection and implementation of new point of sale systems. An interactive website, which includes videos and photographs of each organization and the events that took place, is available for each case study. Students navigated the websites to formulate conceptual models of the events that took place, and relied on them for guidance in all subsequent decisions. Thus, the students engaged in an interactive learning process while working in teams. The same syllabus and course structure were used at each institution, as well as classroom assignments and tests.

Participants

We recruited 84 students from two universities. The sample from the HBCU consisted of 17 students, while the non-HBCU sample consisted of 67 students. In total, there were 14 female students and 70 male students. Students' previous GPAs ranged from 1.50 to 4.00, with a mean of 3.14. Participants were enrolled in an introduction to engineering technology course that applied problem-based learning principles which have been found to influence student perceptions and performance. The specific PBL technique in this study is multimedia case studies. The course at each university consisted of business and engineering students.

Procedure

Data were collected at multiple points during the semester using a combination of self-reported instruments, and grades provided by instructors, decreasing the potential for any negative effects associated with common method bias. Podsakoff, MacKenzie, Lee, and Podsakoff (2003) suggest that data collected from a common source can result in inflated covariances between variables. Specifically, one might observe the inflation or deflation of relationships between constructs, leading to both Type I and Type II errors. Therefore, one of the dependent variables, academic performance (i.e., team score), was provided by the instructor, while the predictor variables were provided by the students.

Each of the presage factors was collected through self-report instruments at the beginning of the academic semester. Perceived team-working skills were collected via an instrument shown to be valid and reliable in a number of studies examining student perceptions (Mbarika 2000; Mbarika et al. 2003a). Self-efficacy was measured using the Longitudinal Assessment of Engineering Self-efficacy (AWE 2009). Finally, the variable labeled average team score was the mean score given to each individual for their work in the three team-based case study projects.

Data analyses

In a descriptive analysis of the 84 matched responses from our instruments, the skewness of all items ranged between -1.86 and -.380, and kurtosis ranged between -.52 and 5.1. Based on the recommendations of Kline (2005), these skewness and kurtosis values are within the acceptable ranges of less than an absolute

value of three, and less than an absolute value of 10, respectively. Additionally, no significant outliers were detected in our analysis.

Using a structural equation model, we examined the hypothesized relationships in Figure 1. In a structural equation model, researchers are able to examine the structure of interrelationships expressed in a series of equations, similar to a series of multiple regression relationships (Hair et al. 2006).

After all available responses from the three instruments were matched, bringing the total number of usable responses to 78, it was evident that individual data points (i.e., responses to individual questions) were missing. Closer examination of the data revealed that missing data percentages for the observed variables ranged from 0 to 3.7. Typically, missing data under ten percent for a specific case or observation can be ignored, except when the missing data occurs in a specific nonrandom fashion (Hair et al. 2010). To determine the randomness of our missing data we applied Little's MCAR test. The results of Little's MCAR test indicated a non-significant difference between an observed missing value pattern and a random pattern with $\chi^2 = 513.42$, $df = 518$, $p = .549$, suggesting that our data could be treated as missing completely at random (MCAR). Therefore, we applied the expectation-maximization (EM) algorithm to impute the missing values, one of many available options (e.g., pairwise deletion, listwise deletion) when data are treated as MCAR.

Due to a small sample size, the items representing each of the constructs were averaged to create a single value for each construct. This process was necessary to produce a model that was identified. Before calculating the path coefficients of our model, we assessed the overall goodness-of-fit of our structural model. The results of our tests, displayed in Table 1, suggest that our structural model adequately fits our data (i.e., $\chi^2/df = 1.294$, CFI = .97, RMSEA = .06, SRMR = .059). All fit indices were within the recommended limits.

Fit Indices	Recommended Value	Structural Model
Chi-square (df)		12.94 (10)
Normed Chi-square	≤ 3.0	1.294
CFI	$\geq 0.9^*$	0.970
RMSEA	$\leq 0.1^*$	0.060
SRMR	$\leq 0.1^*$	0.059

Kline (2005)*

Table 1. Goodness of fit test results

Results

In total, eleven hypotheses were tested using structural equation modeling (SEM). Figure 2 depicts each path coefficient, its level of significance, and the portion of variance explained (R^2 value) for each construct. Figure 2 also displays whether or not each hypothesis is supported.

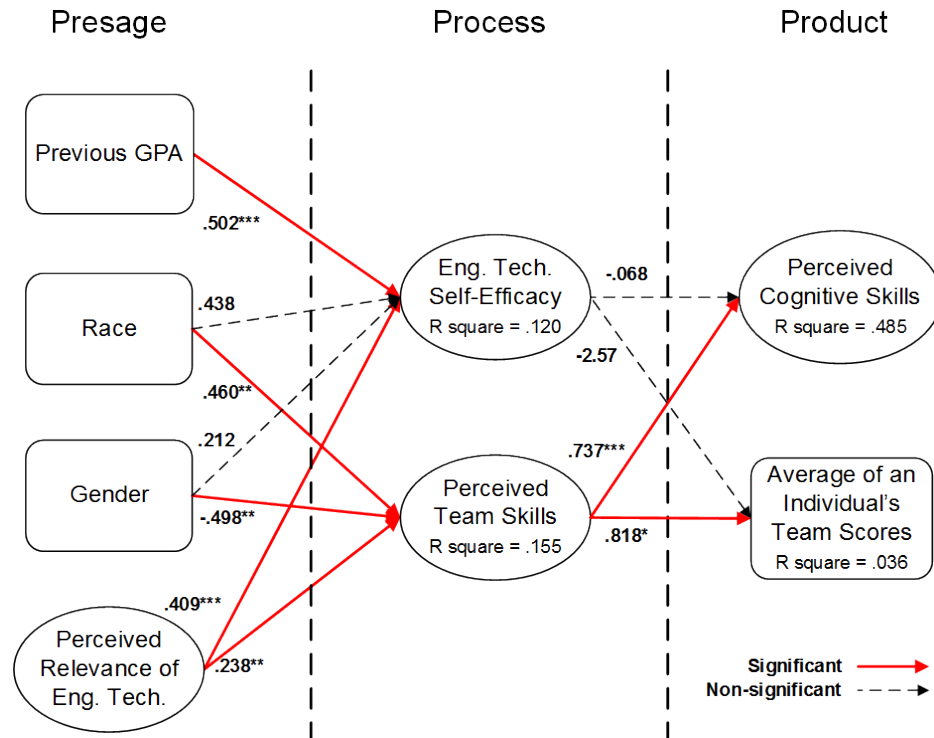


Figure 2. Research model showing the results of our analyses

The results suggest that seven of the eleven hypotheses are supported. As expected, and in support of extant literature, previous GPA is a significant predictor of engineering technology self-efficacy ($\beta=.502, p<.001$), providing support for hypothesis one. Neither race ($\beta=.438, p>.1$) nor gender ($\beta=.212, p>.1$) are significant predictors of engineering technology self-efficacy, meaning that hypotheses two and three are not supported. Further, this implies that self-efficacy does not differ based on the individual's race, or based on their gender. However, a student's perceived relevance of engineering technology ($\beta=.409, p<.001$) is a significant predictor of engineering technology self-efficacy, suggesting hypothesis four is supported. Race is significantly related to an individual's perceived team-skills ($\beta=.460, p<.05$), meaning that support exists for hypothesis five. This suggests that perceived team-working skills differ based on a student's enrollment in a non-HBCU university or an HBCU. Specifically, students at non-HBCUs are more likely to perceive their team-working skills as being higher than students at HBCUs.

While hypothesis six was not supported, a relationship between gender and individual perceived team-skills was present in the data ($\beta=-.498, p<.05$). Specifically, we observed that females perceived their team-skills as being higher than males. The final presage factor in our model, perceived relevance of engineering technology, is also related to perceived team-skills ($\beta=.238, p<.05$), hypothesis seven. Support for hypothesis seven suggests that the level at which a student perceives engineering technology to be relevant is positively related to the student's perceptions of their team-working skills. In total, presage factors accounted for 12% of the variance in engineering technology self-efficacy ($R^2=.120$, coefficient of determination), and 15.5% of the variance in perceived team-skills ($R^2=.155$).

The results of the relationships between process and product factors produced the following results. Engineering technology self-efficacy is not significantly related to perceived cognitive skills ($\beta=-.068, p>.10$), or average team scores ($\beta=-.257, p>.10$), hypotheses eight and nine, respectively. However, perceived team-skills is significantly related to both perceived cognitive skills ($\beta=.737, p<.001$, hypothesis ten), and an individual's average of their team scores ($\beta=.818, p<.10$, hypothesis eleven). Support for hypothesis ten suggests that a relationship exists between perceived team-skills and perceived cognitive skills such that higher student perceptions of team-skills are associated with higher perceived cognitive skills, while holding engineering technology self-efficacy constant. The results of our test of hypothesis

eleven, proffering the existence of a relationship between perceived team-skills and an individual's average of their team scores, suggests that higher student perceptions of team-skills are associated with a higher average of an individual's team scores, while holding engineering technology self-efficacy constant. In total, process factors accounted for 48.5% of the variance in perceived cognitive skills ($R^2=.485$), and 3.6% of the variance in average team scores ($R^2=.036$).

Discussion, Findings, & Limitations

Extant research focusing on STEM education has found disparities between the self-efficacy levels of Caucasian and African-American students, and between the self-efficacy levels of male and female students. Many have suggested that self-efficacy was a key component of success for engineering technology students, and should be used as an explanation for the differences in student performance. However, this study displayed a lack of disparity between students at HBCUs and non-HBCUs (i.e., African-American and Caucasian students) and between male and female students, suggesting that historically held beliefs that African-American students and female students are less confident in their general engineering technology abilities are no longer valid, or are less widespread.

A difference was present, however, in the current study between the perceived team-skills of students at HBCUs and non-HBCUs, such that students at non-HBCUs perceived higher levels of team-skills. This finding might suggest that engineering technology faculty at HBCUs should devote more time to developing the team-skills of their students, as this skill is now being emphasized by employers as a requirement for success as a professional (Shuman et al. 2005). Additionally, females were found to perceive their team-skills to be higher in relation to male students. This finding stands in contrast to past research suggesting that females tend to rate themselves lower than males in team settings (Scherpereel and Bowers 2008).

Another relationship that provides direct feedback to instructors seeking to find appropriate methodologies is between an individual's perceived relevance of engineering technology and both self-efficacy and perceived team skills. The practical nature of this result might suggest that the use of real-world scenarios, such as multimedia case studies, allows students to see the direct relationship between course content and problems faced by industry, resulting in higher performance and self-perceptions. When considering the model in its entirety, we find that students who perceived engineering technology to be relevant, reported increased perceived team-skills, resulting in improvement in average team scores and perceived gains in higher-order cognitive skills. The heavily researched relationship between enactive master experience (i.e., GPA) and self-efficacy held true in the current study, however, no significant relationships were present between self-efficacy and performance.

The primary limitations of this study involve the size and symmetry of the sample. The overall sample size used in this study is often considered too small for a robust SEM analysis and could potentially result in inflated Type I and Type II errors. According to Kline (2010), it is generally true that SEM is a large sample technique, and some statistical estimates may not be accurate when sample sizes are not large. Additionally, there are disparities present between the number of African-American students and Caucasians, and between the number of males and females involved. In an ideal sample, equal sizes would exist across the aforementioned demographic characteristics, providing the researcher with a greater probability to observe differences or similarities when they exist. However, a real-world scenario limited both the demographic makeup and the size of the sample in this study. Specifically, the HBCU involved in this study had smaller class sizes than the non-HBCU. Furthermore, all schools of engineering suffer from a disproportionately smaller number of females in engineering degree plans, and some have reported that the number of females enrolled in engineering has continually decreased in recent years (Trenor, Yu, Waight, Zerda, & Ting Ling, 2008). Future researchers should conduct similar studies with samples containing larger ratios of females to males and a larger overall sample size, if possible, to further support or reject our findings.

Some individuals might also argue that our use of GPA, rather than specific abilities is not sufficient because it does not account for course content. While this argument is valid, GPA was the closest available variable that could be used to represent an individual's enactive mastery experiences.

Conclusion

This study provides needed insight into the relationships between presage, process, and product variables in an undergraduate multimedia instructional technology classroom. While further research is necessary to clarify many of the relationships in this study, past findings regarding the influence of race and gender on self-efficacy were not observed in this study, opening the door for future studies aimed at explaining the differences in enrollment and graduation rates of minorities. Further, self-efficacy and perceived team-skills mediate the relationships between certain presage factors and product factors, suggesting that students' perceptions when entering engineering can influence their academic performance. A logical extension of this finding would be to examine the educational experiences of engineering students prior to college that led to positive or negative perceptions of engineering. In an attempt to extend the team-skills research, which suggests that team-skills training is necessary to observe real gains in student performance, academicians may wish to provide team-skills training and use perceived team-skills as a proxy for determining a student's readiness to perform in a team setting. Seat et al. (2001) suggest that working with people is a learned skill, but the engineering discipline needs programs that teach these skills in a way that appeals to engineering students. The multimedia instructional methodology used in the current study appears to be one such method for teaching these skills.

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