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Promoting First-Semester Persistence of Engineering Majors with Design Experiences in General Chemistry Laboratory

Mr. Corey Payne, University of Florida
Dr. Kent J. Crippen, University of Florida

Kent Crippen is a Professor of STEM education in the School of Teaching and Learning at the University of Florida and a Fellow of the American Association for the Advancement of Science. His research involves the design, development, and evaluation of STEM cyberlearning environments as well as scientist-teacher forms of professional development. Operating from a design-based research perspective, this work focuses on using innovative, iterative and theoretically grounded design for the dual purpose of addressing contemporary, complex, in situ learning problems while concurrently generating new theoretical insight related to the process of learning and the relationships among the people, tools and context of the problem space.

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Abstract

In an effort to address the persistence of undergraduate engineering students taking general chemistry, typically a prerequisite course during the first two-years on campus, we have created a career-forward laboratory curriculum. This curriculum involves student teams completing Design Challenges, which translate chemistry concepts such as specific heat capacity, solubility, and reaction kinetics into situated problems that are unique to the practice of professional engineers. In addition to contextualizing science and engineering as real world applications, our approach forecasts the professional practice of various types of engineering careers. This approach allows first- and second-year students to experience the work of a professional engineer in a developmentally appropriate form as a means of learning the domain of chemistry. Special consideration has also been given to designing for populations sensitive to cultural and institutional issues, which include using universal/global engineering issues in lieu of engineering problems and formalized collaboration.

This paper reports on a field study assessing self-efficacy (for engineering and for teamwork) and identity as an engineer as mediating variables to the outcome of commitment to an engineering career across one-semester for two-groups. The comparison condition was a more typical chemistry inquiry curriculum that was operationalized as business-as-usual (BAU). Specifically, we asked, what impact does use of the career-forward curriculum have on self-efficacy, identity as an engineer and commitment to an engineering career, and in particular, for students identifying as female or as a member of an underrepresented ethnic minority (URM)?

As a course-based professional experience, we view the career-forward curriculum as a form of research experience, which is consistent with the Mediation Model for Research Experiences (MMRE), the theoretical framework. This model suggests that the relationship between the student's experience and their long-term commitment to pursuing an engineering career is mediated by the interaction between their self-efficacy and identity as an engineer. Accordingly, content specific self-efficacy, such as for science or engineering, is a strong predictor of achievement for undergraduate students, predicting interest, achievement and persistence for engineering majors. For URM students, a lack of this form of efficacy has been shown to foreshadow a change of majors. Teamwork self-efficacy represents the assumed need for confidence in one's collaboration abilities when working in design teams. Identity as an engineer, which encompasses a student's sense of fit within the engineering community, is emerging as an important indicator of persistence. Increasing URM students' propensity to feel, think, and behave as a practicing engineer will promote the likelihood of their internalizing positive and productive beliefs about both the domain, their identity as such a person, and their participation in an engineering career.

This quasi-experimental study involved a comparison across two-conditions at two-points across one-semester. Data was collected using a survey instrument that was validated for use with the MMRE. The research question was addressed with one-way multivariate analysis of variance

(MANOVA). When disaggregating the groups by gender and URM status, one-way analysis of variance (ANOVA) was used because the bivariate correlations among constructs were low (<0.2). The participant pool was a convenience sample of 169 undergraduate students who elected to take a lecture course titled *General Chemistry for Engineers* during the Fall semester at a large public research university in the southern United States and provided informed consent for the research. In parallel and without prior knowledge, participants self-enrolled in a laboratory course where two-sections represented our comparison and intervention conditions, one using the BAU laboratory curriculum or the second using the career-forward curriculum. URM status was determined based upon self-identification using the ethnic groups defined by the National Science Foundation.

Results for the entire sample indicated no significant difference by condition for any of the four-tested variables ($F(3, 164)= 2.101$, $p=0.101$ Wilk's $\Lambda = 0.963$, partial $\eta 2 = .037$) as well as when disaggregated by gender ($F(4,72)= 0.488$, $p=0.744$ Wilk's $\Lambda = 0.974$, partial $\eta 2 = .026$). In general, and for our female identifying participants specifically, any impact due to the different forms of curriculum on persistence and commitment was not distinguishable. However, differences were detected when the data was disaggregated by URM status, indicating a significant positive difference for Engineering self-efficacy with a medium positive effect ($F(1,50)= 5.784$, $p= 0.020$, $\eta 2 = 0.104$) and large negative effect for commitment to an engineering career ($F(1,50)= 40.764$, $p= 0.000$, $\eta 2 = 0.449$). This suggests that even as students who identify as URM increase their confidence in their ability to complete engineering tasks they actually become less committed to an engineering career. However, no significant difference was found for identity as an engineer ($F(1,50)= 0.867$, $p= 0.356$, $\eta 2 = 0.017$) or teamwork self-efficacy ($F(1,50)= 2.340$, $p= 0.132$, $\eta 2 = .044$). These results suggest that in general, participants using the career-forward curriculum are achieving the same level of decline in persistence as their BAU peers, which is consistent with trends described in the literature. However, for URM participants, the career-forward experience results in a small/medium positive effect that is specific to Engineering self-efficacy, an encouraging result.

The decrease in commitment to an engineering career for URM students suggests that some aspect of the curriculum is likely causing issues. Considering the positive trend for Engineering Self Efficacy among this group, indicative of increased confidence for *doing engineering*, this is an especially intriguing and concerning result, which may be related to stereotype threat where our focus on career practices causes URM students to project negative feelings or experiences forward into their career. These findings merit further study.

Keywords: Undergraduate, Gender, Race/Ethnicity, Engineering

Introduction

In an effort to address this issue of persistence for undergraduate students majoring in engineering and taking general chemistry, typically one of the pre-requisite courses taken during the first two-years on campus, we have developed a career-forward laboratory curriculum that is designed to support persistence. A career-forward curriculum targets the long-term goal of persistence—the personal capacity of students to continue towards an academic goal—by framing experiences with the content, context and specific skills of working in the target career field. Created as an extension of an earlier reform of the recitation component of chemistry courses [1], this curriculum involves student teams completing Design Challenges (henceforth Challenges), which translate general chemistry concepts such as specific heat capacity, solubility, and reaction kinetics into contextualized and situated problems and methods that are unique to the practice of professional engineers. In addition to contextualizing science and engineering as real world applications, our approach forecasts the professional practice of various types of engineering careers.

This career-forward approach allows first- and second-year students to experience the work of a professional engineer in a developmentally appropriate form as a means of learning the domain of chemistry. The new curriculum is designed to maintain student motivation and persistence for an engineering major by helping them to better understand engineering as both a practice and career. The curriculum has been designed to be supportive of all students with a focus on the global application of engineering and chemistry principles. Special consideration has also been given to populations sensitive to cultural and institutional issues such as students who identify as female and/or as a member of an underrepresented ethnic minority (URM), these include using universal/global engineering issues in lieu of engineering problems that typically interest male students and formalized collaboration to avoid creating a competitive environment based on individual work [2], [3].

In keeping with the philosophy of authentic science and engineering practice, it is important to make explicit not just the content to be learned, but the array of skills students will need in these careers. A key component of successful career work in engineering is the ability to work as a part of a collaborative group or team. In the 2018-2019 criteria from the Accreditation Board for Engineering and Technology (ABET)—the governing body for undergraduate accreditation—student outcomes related to collaboration and teamwork are directly referenced as part of "prepares graduates to enter the professional practice of engineering" (p. 39). As the field of engineering moves forwards and adapts to the changing needs of the world, the importance of helping engineering students learn not just how to solve engineering problems, but how to do so in the types of environments they will be embedded in during their careers [4] become more paramount.

As an initial step in evaluating the effectiveness of our career-forward curriculum, this paper reports on a field study assessing self-efficacy (for engineering and for teamwork) and identity as an engineer as mediating variables to the outcome of commitment to an engineering career across one-semester for two-groups of undergraduate students taking general chemistry laboratory. The comparison involves the use of the new curriculum with that of a more typical science inquiry approach that represents business-as-usual (BAU). In an effort to assess the general effectiveness as well as its specific capacity for supporting students identifying as URM, we sought to answer the following research question: What impact does use of the career-forward curriculum have on self-efficacy, identity as an engineer and commitment to an engineering career, and in particular, for students identifying as female or URM?

For our purposes it is important to clearly define how the terms persistence and commitment are conceptualized and measured, both of which are consistent with the Mediation Model of Research Experience (MMRE) [5], which served as the theoretical framework. Commitment is defined as the student's willingness to persist towards a specific long-term goal, in this case an engineering career and was measured as an outcome variable through a set of items that loaded directly to the construct. Persistence is the ability of students to continue towards an academic goal even through adversity or difficulties over a period of time [6]. It was measured by the constructs of self-efficacy, both engineering and teamwork, and identity as an engineer, which represent unique psychological processes. As a course-based professional experience, we view the career-forward curriculum as a form of research experience, which is consistent with Chemers et al. definition [5] as well as examples from other studies.

Theoretical Framework

The MMRE model (Figure 1), which was initially developed based upon survey responses from members of the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), proposes that experiences that are designed to support students (i.e., support components) serve to effect their psychological processes of persistence, which in turn influences their long-term commitment to a career.

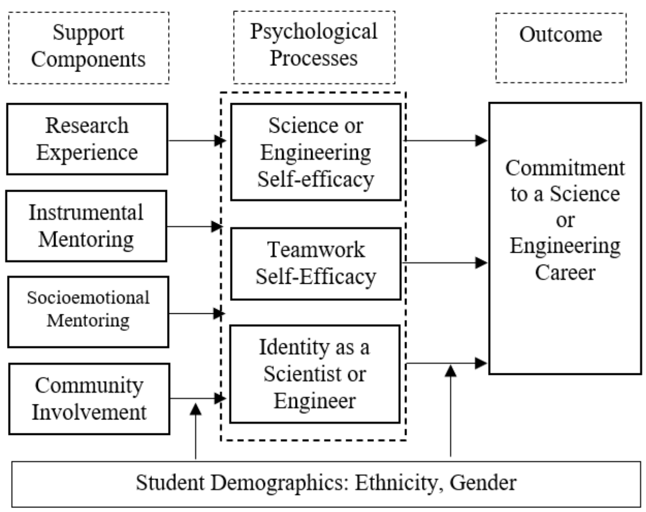

Figure 1. MMRE model of intentional student support influencing the mediating psychological processes of persistence, which in turn influences long-term commitment to a career, adapted from [5].

This model suggests that the relationship between the experiences most often provided by an academic support system and a student's long-term commitment to pursuing a degree/career in a STEM field is mediated by the interaction between the student's science/engineering self-efficacy and identity as a scientist or engineer. While the MMRE was initially proposed to explore the context of science learning [5], it has also been shown to be applicable when studying students majoring in engineering [7]. When used in a science context, the constructs and scales for science self-efficacy and science identity are used [5] and unique scales for engineering self-efficacy and identity are used for engineering contexts [7]. The four-categories of support have been derived from an on-going review of research and are not mutually exclusive [8], [9].

In this study, Research Experience functions not as a variable, but as the socio-cultural context of our career-forward curriculum, which is predicted to influence the psychological processes and , accordingly, commitment to a career.

Self-Efficacy

Self-efficacy describes one's beliefs in their ability to accomplish a particular task and achieve a defined outcome [10]–[12]. These beliefs are recognized as being task or content dependent and as such have been shown to have good predictive value for behavior [13]–[15]. Individuals with high levels of self-efficacy tend to view effort as the means to task success, even in the face of difficulty or failure.

The MMRE recognizes two-specific forms of self-efficacy, engineering and teamwork, which relate to the career-forward nature of the curriculum as participant beliefs regarding the content, context and specific skills that serve as desired outcomes. Content specific self-efficacy, such as for science or engineering, is a strong predictor of achievement for undergraduate students [16], [17]. In particular, it predicts interest, achievement and persistence for undergraduate students majoring in engineering [3], [18], [19]. For underrepresented students, a lack of this form of self-efficacy has been shown to foreshadow a change of majors and leaving engineering [18], [20]. The inclusion of teamwork self-efficacy as a skill-specific form is based upon the assumed need for confidence in one's collaboration abilities when working in design teams [21], but to date it has been understudied. Using the MMRE, Chemers, Hu & Garcia [22] found that self-efficacy was a strong and significant predictor when examining student health, goals and academic performance.

Identity as an Engineer

Identity as an engineer, which describes a student's perceived sense of fit within the community of engineering (in general as well as with their peers), is an important aspect of persistence in engineering education. Identity as a scientist or engineer are but one of many multiple social identities that students develop, navigate between, and merge into their personal identity [5], [16], [23]. Cech, Rubineau, Silbey, and Seron [24] found that for women, their perceptions of performance as well as their confidence in their engineering skills are generally less than males and propose the construct of professional role confidence—"individuals' confidence in their ability to successfully fulfill the roles, competencies, and identity features of a profession" (p. 642)—as a key explanatory variable for persistence. For female students, the early development of an identity as an engineer is likely to support the long-term choice of engineering as a career [25]. Part of a student's professional identity stems from their sense of belonging. This sense of belonging can be related to how included they feel, which encompasses their views on representation within the field or the social pressures they feel from both peers and mentors. This goes beyond a student's abilities or external sources of motivation and is a reflection of their internalized conception of self. If a student does not feel that they belong on a learning track, degree path or ultimately in the profession (i.e., professional identity), it does not matter how confident they are in their knowledge and skills (i.e., self-efficacy), they are less likely to stay this course.

Understanding and supporting a student's context specific identity (i.e., identity as a scientist or engineer) is an important factor in creating materials and interventions that intend to encourage persistence. Some studies have shown that the most effective way to predict performance and persistence is through the use of context relevant identities instead of gender or racial/ethnic identities [26]. For example, URM students' knowledge and comprehension of science can be enhanced via their participation in well-structured undergraduate research programs [27]. This participation can also have positive effects on helping URM students to better understand their own desires to pursue post-baccalaureate programs or careers in scientific fields [23]. By increasing URM students' propensity to feel, think, and behave as a 'science or engineering person,' promotes the likelihood of internalizing their beliefs about both the domain, their identity as such a person, as well as their ability to successfully participate in the field [28]. A student's identity as a scientist or identity as an engineer is only one of the myriad social identities that students must integrate [5], [16], [23]. Results from research using the MMRE show that of the mediating variables identity as a scientist had the highest predictive power for long term commitment to a science career [5].

Commitment to Engineering Career

The final component of the MMRE is the long-term outcome, commitment to a science or engineering career, which is defined as the students' intentions to work in the field of science or engineering after their formal education. According to Syed et al [7], when establishing the MMRE model, the predictive paths towards commitment to a science or engineering career were selected based on prior research into the concepts of affirmation and identity in part due to their prevalence in academic research across a variety of areas of psychology. The MMRE focuses specifically on long-term commitment to a career and even more specifically focuses on the professional career following formal education.

Review of Research Related to Curriculum Design

Problem-Based Learning (PBL) was selected as a key design element for the curriculum based on its potential to be supportive of learning for all students. PBL is an educational design approach which guides learners to "conduct research, integrate theory and practice and apply knowledge and skills to develop a viable solution to a defined problem" [29]. PBL has been shown to increase long term knowledge retention, the motivation of learners and their ability to solve authentic problems [30]. More specifically, PBL has been shown to be effective in helping the persistence of underrepresented students in STEM. For example, in a case study of at-risk female students in a physics classroom, the use of a PBL curriculum was shown to have positive effects on both student collaboration and self-efficacy [31]. An additional exploratory study demonstrated that one-month of a PBL curriculum in a STEM environment helped students better understand the importance of improving both their own abilities as well as skills that will help them specifically in their careers [32]. With the emphasis on authentic engineering problems and a developmental form of professional practice, a career-forward curriculum is one-form of PBL.

A career-forward curriculum targets the long-term goal of persistence by framing student experiences with the content, context and specific skills of working in the target field. When focusing specifically on engineering as the target career, the approach uses authentic engineering problems to define the content and context. The content and context need to be based on the work of professional engineers, more than just a similar topic, they need to involve a developmentally appropriate facsimile to what the problem would be as well as the social arrangements and practices of iterative design. The specific skills of a career-forward curriculum for engineering focuses on what ABET has defined as *professional skills*, which are guidelines for the type of collaborative teamwork and communication skills that engineers must have in order to work successfully in the field [33].

Methodology

This field test involved a quasi-experimental study across two-separate conditions comparing student engineering and teamwork self-efficacy, identity as an engineer, and commitment to an engineering career at two-points across one-semester. This data was collected using a pre/post repeated measure survey, which was constructed for use with the MMRE and previously found to be valid and reliable [5]. The research question was addressed with a combination of one-way multivariate analysis of variance (MANOVA) and as necessary, one-way univariate analysis of variance (ANOVA).

Participants

The participant pool was recruited as a convenience sample of 169 undergraduate students who elected to take a lecture course titled *General Chemistry for Engineers* during the fall semester at a large public research university in the southern United States (Table 1), where they provided informed consent for the research. In parallel and without prior knowledge, participants self-enrolled in a laboratory course where two-sections represented our comparison and intervention conditions, one using the BAU laboratory curriculum and the second using the career-forward curriculum. As part of the informed consent process, participants were given the option to transfer to other sections, but none did. All participants were enrolled in the same lecture section, which used a special curriculum for engineering majors. In total there were 77 participants that identified as female and 52 participants that identified as URM across the two-conditions. URM status was determined based upon self-identification using the ethnic groups defined by the National Science Foundation [34].

Table 1. Summary of participant demographics across groups.

	Career-Forward	BAU
Overall	86 (51%)	83 (49%)
Gender		
Female	41 (48%)	36 (43%)
Male	42 (49%)	46 (55%)
URM Status		
URM	24 (28%)	28 (34%)
Non-URM	62 (72%)	55 (66%)

Course Description

The multi-phase career-forward curriculum combined aspects of problem-based learning with those of an engineering career (Table 2). Challenges were constructed using an iterative design-based approach that prioritized student feedback [35]–[37] and were each carried out over three-laboratory sessions in three-phases; Design, Conduct, and Analyze and Interpret (Figure 2).

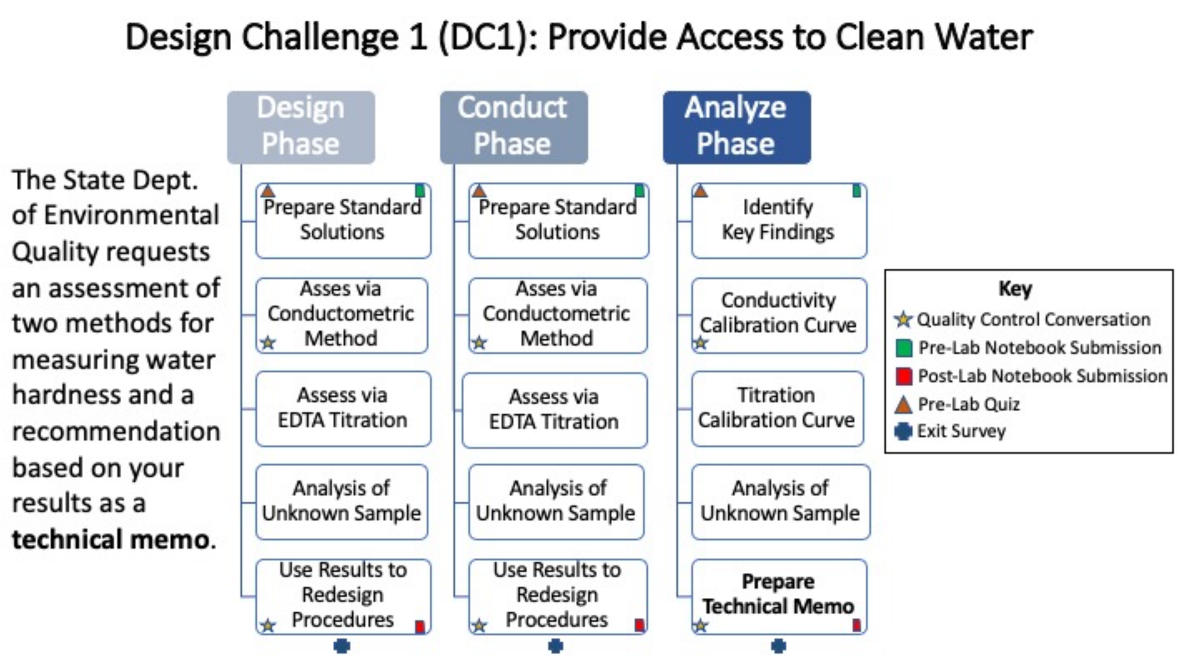

Figure 2. Overview of a Design Challenge.

During the Design Phase, teams define the problem, including constraints and criteria, then perform experiments to obtain preliminary data that is used to propose an initial design. During the Conduct Phase, teams perform additional experiments and use these results to refine their design. Finally, during the Analyze and Interpret Phase, teams propose a final design as part of a technical memo, including any further experiments they deem necessary. The phases represent the design process and are based upon ABET Student Outcomes (criteria b) (see [35]–[37] for a more in-depth description with examples). The semester consisted of one condensed Challenge that was completed in the first single laboratory session then three-full Challenges. The Challenges were completed by teams of two- to three-randomly paired students who worked together for the entire semester. The course instructor deemed random assignment as the most efficient and economical means for assigning teams. Intentional assignment has been used in previous instances, but was perceived as too difficult to implement, overly prescriptive and not consistent with the future career context.

Table 2. Grounding for elements of the curriculum as problem-based [38] and career-forward.

Curriculum Element	**Problem-based Feature**	**Career-Forward Feature**
Teams work on compelling real world engineering problems [39].	Ill Structured Problems	Challenges are presented as client-driven problems [40].
Students work in teams and choose the pace and methods. Claim-evidence-reason tables are used for chemistry content and recommendation-evidence-reasoning tables for design thinking.	Student Centered	*Quality Control* checklists and signatures ensure shared participation and accountability [36].
Teaching Assistants are trained facilitators with probing questions.	Teacher as Facilitator	*Quality Assurance* checklists and signatures ensure conversations with the teaching assistant and accountability [36].
Challenges were developed by an interdisciplinary design team of faculty from engineering and chemistry.	Authentic Problems	Challenges are couched in one the 14 NAE Grand Challenges for Engineering [39] where each is based upon a unique type of engineering.

Measures

The measures used and reported are adapted from the psychological process items first used in [41]. Items were modified to refer to engineering as the specific content area as opposed to science as a general construct. These items were previously analyzed to ensure each construct was a single factor and that the items not loading were removed from the survey and further analysis [5].

Engineering Self-Efficacy

The engineering self-efficacy scale was built to measure the confidence in one's own ability to successfully work as an engineer. There were ten items on the survey that asked students to rate their agreement to statements about their ability to complete various tasks. Examples of the tasks were "I can excel in an engineering major during the current academic year." and "I can persist in an engineering major during the next year." Participants responded on a Likert-type scale from 1 (strongly disagree) to 5 (strongly agree). The resulting Cronbach's alpha for the scale was 0.895 for all participants.

Teamwork Self-Efficacy

The teamwork self-efficacy scale was developed to measure the student's confidence in their ability to successfully work as part of a team. The scale included five-items that described teamwork in terms of both communication and collaboration. An example of items addressing teamwork was "I know what it takes to help a team to accomplish a task." Participants responded using a 5-point Likert-type scale with 1 being strongly disagree and 5 being strongly agree. Cronbach's alpha for the scale was determined to be 0.947.

Identity as an Engineer

Identity as an engineer is based on how students view being an engineer as an integral part of their personal identity. Consisting of six-items, participants were asked to reflect inward and respond to questions to help the researchers "understand how much you think that being an engineer is part of who you are." An example item is "I feel like I belong in the field of engineering." Students rated their agreement on a 5-point Likert-type scale with 1 being strongly disagree and 5 being strongly agree. Cronbach's alpha for the scale was determined to be 0.940.

Commitment to an Engineering Career

Commitment to an engineering career functions as an outcome variable within the MMRE. It was designed to measure a student's intent to continue in the engineering field as a career after their academic degree. This construct was adapted to measure intent to work in the field of engineering instead of the more general field of science. The scale included 7 items such as "I will work as hard as necessary to achieve a career in engineering." Cronbach's alpha for the scale was determined to be 0.966.

Analysis

The survey data was first used to calculate normalized gain scores for the four-variables, defined as the difference in survey responses between the final Challenge and the pre-survey divided by the difference in maximum possible score and the pretest score (Table 3). A MANOVA was used to compare the mean differences in normalized gain scores for the four-constructs between participants overall from the career-forward curriculum compared to the BAU group. All assumptions for MANOVA were met for the comparison overall between participants in both groups. When disaggregating the groups by gender and minority status, ANOVA was used instead of MANOVA because the bivariate correlations among constructs were low ($\rho < 0.2$). One-way ANOVAs were used to determine differences between the PBL and BAU groups when disaggregated by gender (females only) and URMs. The statistics reported for each of the analyses were the F-statistic, p-value (alpha level < 0.05), and eta-squared ($\eta 2$). Eta-squared is an effect size measure for the variance associated with each variable and the values can range from 0 to 1. The following cut points were used for interpretation: 0.01 (small), 0.06 (medium), and 0.14 (large) [42].

Results

Descriptive statistics are presented in Table 3 for the two-conditions. A comparison of the entire study sample by condition indicated no significant difference for any of the four-tested variables ($F(3, 164)= 2.101$, $p=0.101$ Wilk's $\Lambda = 0.963$, partial $\eta 2 = .037$). The comparison between conditions when disaggregated by gender also indicated no statistically significant difference or any of the four-variables ($F(4,72)= 0.488$, $p=0.744$ Wilk's $\Lambda = 0.974$, partial $\eta 2 = .026$). These results suggest that in general and for our female identifying participants specifically, any impact due to the different forms of curriculum on persistence and commitment was not distinguishable.

Differences were detected, however, when the data was disaggregated by URM status. For URM participants, there was a significant difference found for engineering self-efficacy with a medium positive effect ($F(1,50)= 5.784$, $p= 0.020$, $\eta 2 = 0.104$) and large positive effect for commitment to an engineering career ($F(1,50)= 40.764$, $p= 0.000$, $\eta 2 = 0.449$). For engineering self-efficacy, the URM students using the career-forward curriculum showed an increase in this form of self-efficacy compared to the decline documented for the students in the BAU course. URM students using the career-forward curriculum had decreased levels of commitment to an engineering career compared to the students in the BAU course. These results indicate that even as students who identify as URM increase their confidence in their ability to complete engineering tasks they actually become less committed to an engineering career. However, no significant difference was found for identity as an engineer ($F(1,50)= 0.867$, $p= 0.356$, $\eta 2 = 0.017$) or teamwork self-efficacy ($F(1,50)= 2.340$, $p= 0.132$, $\eta 2 = .044$). These results show that using a career-forward laboratory curriculum has a small positive effect on the engineering self-efficacy of URM students, but a problematic impact on long-term commitment to an engineering career.

Table 3. Descriptive comparison of the participant groups.

	Business-as-Usual (BAU)							Career-Forward						
	Pre			Post			Normalized Gain	Pre			Post			Normalized Gain
	n	M	SD	n	M	SD	M	n	M	SD	n	M	SD	M
Overall														
Commitment to Engineering Career	83	4.3956	0.4971	83	4.1153	1.0140	1.0000	86	4.3870	.7303	86	4.2409	0.9324	-0.4560
Identity as an Engineer	83	3.6064	0.8504	83	3.6204	1.0390	-0.2358	86	3.6334	.9565	86	3.7016	1.0889	0.1203
Engineering Self-Efficacy	83	4.3956	0.4971	83	4.3394	0.5735	-0.4361	86	4.2558	.5967	86	4.3226	0.7400	0.0388
Teamwork Self-Efficacy	83	4.5807	0.5279	83	4.5928	0.5314	-0.0645	86	4.5581	.4793	86	4.5535	0.5266	0.0380
URM														
Commitment to Engineering Career	28	4.4786	0.8488	28	4.1582	0.9746	1.0000	24	4.375	0.9063	24	4.2917	1.0271	-0.1962
Identity as an Engineer	28	3.6964	0.8535	28	3.7803	1.0731	-0.1865	24	3.5694	0.8652	24	3.75	1.0333	0.1847
Engineering Self-Efficacy	28	4.4762	0.4773	28	4.3095	0.6770	-0.7222	24	4.2361	0.5199	24	4.4514	0.5372	0.3290
Teamwork Self-Efficacy	28	4.6	0.4714	28	4.5286	0.5367	-0.2282	24	4.4083	0.6283	24	4.5167	0.5467	0.0862

Discussion

These results suggest that in general, participants using the career-forward curriculum are achieving the same level of success in the measured variables as their peers in the BAU course. Considering the extra levels of effort and time required of the students, this is an encouraging result. These students were conducting more realistic experiments requiring collaboration, they were using critical thinking and decision-making to reason about design constraints, and were developing consensus and ultimately constructing professional-style deliverables. All of this was achieved while maintaining high levels of career commitment, identity and self-efficacy throughout the semester. This contrasts with the more typical decreasing trend that is commonly described in other studies with a similar demographic and context [43].

Encouraging positive effects were indicated when results were disaggregated by URM status. Use of the career-forward curriculum resulted in a small/medium positive improvement in engineering self-efficacy for URM participants, a positive impact on persistence. This result contrasts with the slight decrease in engineering self-efficacy observed for the BAU group, which is also consistent with trends described in the literature [43]. This represents the first time in the implementation of this curriculum that there has been a positive gain in engineering self-efficacy for any group of students. Earlier versions of the intervention have shown sustained engineering self-efficacy over a single semester, but not an increase.

The positive results for engineering self-efficacy among URM participants using the intervention are tempered by the negative change in commitment to an engineering career for this group. Since this difference was not found in the comparison group of predominantly white participants, it suggests some aspect of the curriculum design is specifically causing issues for URM students. It is possible that this finding is related to stereotype threat [26] and that by focusing on the career implications of this form of work, URM students are projecting any negative experiences or feelings forward, across their entire career and those predicted negative feelings are causing them to be less committed to a career in engineering. This is an especially interesting result in relation to the findings for engineering self-efficacy, which implies that the decrease in career commitment is not due to student's beliefs about their ability to succeed in the course, but instead must be the result of other pressures. These findings clearly merit further.

Limitations and Future Directions

The inability to analyze the MMRE model for both URM students as well as students that identify as female was the major limitation for this study, as the sample size did not allow disaggregation of female students that were not also part of the URM group due to lack of sufficient statistical power for making meaningful inferences. Due to concerns about intersectionality, it was deemed inappropriate to make any claims about the curriculum's effect on gender. Future direction for this research includes a new sample that raises the number of participants from three-sections of laboratory to eleven, which should produce a sample large enough to disaggregate by both gender and URM status while paying the necessary attention to intersectionality and statistical power.

Fidelity of implementation is another potential limitation. Though the curriculum was designed and usability tested before being field tested, the laboratory courses were run by graduate teaching assistants who were trained, but not involved in the development of the curriculum. While a member of the design team regularly met with them, there is still the possibility that each section received a laboratory experience inconsistent with the others.

The final potential limitation is the lack of explanatory qualitative data. The relationships between the measured constructs, while statistically valid, may lack the depth of explanation that some qualitative measures may be able to provide. Future qualitative study is needed to explore the teamwork experiences of URM students in order to document and explain the negative relationship between teamwork self-efficacy and commitment to an engineering career. In particular, to investigate stereotype threat or forms of marginalization as possible explanations for this phenomenon. The quantitative nature of the present study would greatly benefit from the explanatory power of such a future study.

The results of this study should be interpreted with a degree of caution as it is extremely difficult to isolate the effect of one course on what are complex constructs. The laboratory course is not an isolated experience, but one that is occurring in a larger sociocultural milieu where participant perspectives are being influenced by a range of experiences outside of the course. From a curricular perspective, prior research has shown that the mathematics and engineering mechanics sequence outweigh the influence of courses like chemistry on these outcomes [44], [45], and for URM students in particular, variables like climate within a program are likely important as well [46], [47].

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