AC 2010-878: SPECIAL SESSION: ASSESSING MORALITY, IDENTITY, AND MOTIVATION IN A FIRST-YEAR MATERIALS ENGINEERING SERVICE LEARNING COURSE

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Assessing Self-Efficacy, Identity, Morality, and Motivation in a First-Year Materials Engineering Service Learning Course

Abstract

The Materials Engineering Department at California Polytechnic State University offers a year-long, three quarter engineering service learning experience to 35 – 50 first-year students each year. The goals for the course sequence are 1) to provide students with the skills, relationships, and motivation to succeed within the department, and 2) to increase student satisfaction and retention. Over the three quarters, we provide students with several activities and design projects, culminating in a final service learning project with a local not-for-profit organization.

The intent of this paper is to present an initial assessment of the effectiveness of a service-learning experience on several outcomes including retention, student satisfaction, self-efficacy, motivation, identity, and moral reasoning. We utilized a number of psychological instruments to measure constructs which we believe underlie the course goals described above. Initial results indicate that the most significant gains experienced by the students were in their moral reasoning, school and peer attachment, and design and self-directed learning self-efficacy. We also observed that retention of students at the end of the year was strongly predicted by satisfaction with the experience and learning self-efficacy. Satisfaction with the course was in turn strongly predicted by students' gains in intrinsic motivation, positive interactions with their service learning community partners, and the quality of their classroom interactions with peers and faculty.

Introduction

In the report *The Engineer of 2020* from the National Academy of Engineering,[1] leaders within the engineering education community propose a new vision for undergraduate engineering education that is focused on providing students with attributes such as creativity, agility, ethical reasoning, leadership, and autonomous thinking in addition to the traditional analytical and design skills already present in engineering curricula. To achieve this vision, it seems probable that new approaches to teaching will be necessary. Service learning has been identified as one such approach.[2]

According to the Corporation for National and Community Service, service learning is "a teaching and learning strategy that integrates meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities".[3] Service learning has been shown to benefit students with knowledge acquisition,[4] cognitive development[5], commitment to social justice,[6] socio-moral development[7] and self-efficacy.[6] Given these generally positive results, service learning would seem to be an attractive approach to providing students with the attributes described above.

Engineering education seems well suited to service learning given both the project-oriented nature of the discipline and the place of service to society as a fundamental aspect of engineering professionalism. Though there have been successful applications of service learning within engineering, most notably the EPICS program at Purdue,[8] relatively little attention has been paid to the educational and psychological outcomes associated with effective service learning programs.

Following a significant curriculum reform effort, the Materials Engineering Department at California Polytechnic State University (Cal Poly) incorporated a service learning component within its first-year design sequence to provide students with the attributes described in *The Engineer of 2020* report.[1] The resulting course has been offered for the past three years, and during the Fall 2008 – Spring 2009 academic year, we conducted a thorough assessment of the impact the course was having on students.

The goal of this paper is to describe the effects of a first-year service learning design experience on several psychological constructs including motivation, identity, moral reasoning and self-efficacy. It also describes how changes in these constructs and students' perceptions of the quality of the first-year experience are related to students' overall satisfaction with the first-year program and their intention to continue studying materials engineering.

First-Year Course Sequence

The Materials Engineering Department at Cal Poly underwent a considerable curriculum reform effort from 2005 – 2009 as a result of a National Science Foundation Department Level Reform Grant (DUE EEC-0530760). One outcome of this reform effort was the realization that a new first-year experience was needed to increase student retention from the first to second year, increase student satisfaction with their chosen major, and better prepare students for the design-oriented, self-directed curriculum that was being developed for the second and third years of the curriculum.

The resulting first-year experience involves a three quarter (Fall, Winter & Spring) design sequence of courses (MATE 110, 120 and 130). The sequence includes numerous activities and projects, and culminates in a service learning design experience with a local not-for-profit (NFP) organization. Over the last three years NFP organizations have included a mental health facility, local zoo, homeless shelter, women's shelter, after-school recreation program, animal shelter, botanical garden, and several others.

Students meet with a team of two instructors for one 3-hour classroom experience each week during the 10 week quarter. In addition to enrolling in the design sequence courses, first-year Materials Engineering students also enroll in a special section of an introductory oral and written communications course (COMS 102) that runs parallel to MATE 120 in the Winter Quarter. Providing these linked courses allows students to develop communication skills within the context of their first-year engineering projects.

The general goals for the course sequence are to 1) provide students with the skills, relationships, and motivation to succeed within the department, and 2) increase student satisfaction and retention. These goals are further expanded into the course objectives listed on the syllabus as follows:

1. Provide students with confidence in applying a working design process;

2. Provide students with confidence in the use of design tools including needs assessment, computer modeling, and fabrication tools;
3. Provide students with confidence in communicating their design solutions through engineering reports, presentations and design reviews;
4. Improve students' life-long learning confidence and skills, particularly meta-cognition via reflection;
5. Provide students with ample opportunities to build lasting interpersonal relationships with classmates, as well as Materials Engineering students and faculty.
6. Encourage students to consider their commitment to social justice and being a socially responsible engineer;
7. Make students aware of the importance of support courses through direct application of science and math in real-world problems.

To meet these objectives several experiences are presented to the students throughout the first-year sequence. The Fall quarter focuses on building relatedness among students, social responsibility, teambuilding, and awareness of the design process. Students engage in several activities and dialogues during this time. They also conduct a needs assessment around food production for individuals living in developing countries as part of a first exposure to the design process. Near the end of the quarter, student teams carry out a conceptual design of a solar water heater that would reduce fuel costs for rural Californians. During this quarter, most of the students' time is spent inside the classroom practicing various elements of the design process in a safe and supportive environment. Students are required, however, to serve for at least 5 hours at one of several local NFP organizations as part of the course requirement. This experience helps them to feel more comfortable with their client, to have a better understanding of how it operates, and to identify the key personnel within the organization.

During the Winter quarter the student teams design, build, and test their solar water heaters. They are expected to analyze the efficiency of the water heaters based on average solar insolence data and demonstrate that they remained within their $100 budget. The day of testing on the roof of our building is one of the most rewarding experiences for these students, as it is the first time that many of them have ever built anything. While the teams are struggling to build their water heaters, they must also work with their community partners outside of class to conduct a needs assessment of the NFP organization. This experience of developing a needs assessment of a real organization staffed by non-technical individuals is often described by students as the single most challenging aspect of the course sequence. Students are again expected to serve at least 5 volunteer hours at the NFP.

Finally, in the Spring quarter students implement the needs assessment they prepared during the previous quarter. Within the last 10 weeks of the year, they must design and build the resulting system. Student teams are assisted by a third-year student serving as a project manager. The year culminates in a final presentation of the project to the instructors, community partners, and other interested parties. During this quarter, each design team meets with the course instructors once a week for an individual 1 hour design review. Students are expected to facilitate these meetings on their own, bringing agendas and all necessary documentation. Throughout the year, students complete several reflection assignments, with those near the end of the year focusing heavily on how the students have changed as a result of their service project.

Assessment Strategy

To the extent possible we sought existing validated instruments that assessed psychological attributes or constructs that underlie attainment of the course objectives. For example, the objective of social responsibility likely includes, but is not limited to, components of other-directed motivation, moral reasoning, and the formation of an identity as a socially responsible engineer. The course objectives described previously are listed again along the left-most side of Table 1. For each objective a corresponding set of psychological constructs is identified in the table. It should be noted that a number of other assessment tools were used for assessing student design reviews, reflections, and other assignments. Discussion of these tools is beyond the scope of this paper.

Table 1: Course sequence objectives and corresponding psychological constructs

Course Objectives		Self-Efficacy	Motivation	Reasoning	Identity	Relatedness
Design	Process	x				
	Tools	x				
	Communication	x				
Life-long learning		x	x			
Social responsibility			x	x	x	
Interrelationships					x	x
Integration of science and math		x				
Satisfaction and Retention		x	x	x	x	x

The instruments selected to measure the psychological constructs are shown in Table 2. Each construct was measured with at least one instrument, but in some cases several such instruments were used. For example, we defined self-efficacy as the belief that one is capable of performing a certain task or tasks in order to achieve a desired goal. From this definition, it is apparent that any measure of self-efficacy would be highly dependent on the tasks and goals in question. As Table 1 indicates, we were interested in assessing students' self-efficacy surrounding both design and life-long learning. A review of the literature failed to produce validated instruments for either objective. Consequently, we developed our own instrument based on the work of Albert Bandura.[9] As Table 2 shows, the Design Self-Efficacy instrument was divided into sub-scales for each of the three course objectives related to developing students' confidence in design. Each of these sub-scales contained 5 items to which students responded via a 5-point Likert-type scale. Each of these scales was confirmed using factor analysis. Cronbach's alpha for internal reliability is provided for each sub-scale in the last column of Table 2. A similar approach was used for the Learning Self-Efficacy instrument which included two subscales: Lifelong Learning and Science and Math Learning.

Table 2: Psychological constructs and corresponding measurement sub-scales (Instruments marked with an asterisk are available in the appendix)

Construct	Instrument Name	Sub-scale	Acronym	No. of Items	Internal Reliability (α)
Self-Efficacy	Design Self-Efficacy*	Design Process	DSE-DP	5	0.749
		Design Tools	DSE-DT	5	0.858
		Design Comm.	DSE-DC	5	0.730
	Learning Self-Efficacy*	Lifelong Learning	LSE-LL	5	0.794
		Science and Math Learning	LSE-SM	5	0.887
Motivation	Need for Cognition Scale		NCS	18	0.899
	Situated Intrinsic Motivation Scale	Intrinsic Motivation	SIMS-IM	4	0.925
		Internal Regulation	SIMS-IR	4	0.671
		External Regulation	SIMS-ER	4	0.836
		Amotivation	SIMS-AM	4	0.837
	Interpersonal Reflectivity Index	Empathic Concern	IRI-EC	5	0.810
		Perspective Taking	IRI-PT	6	0.793
Moral Reasoning	Defining Issues Test 2	N2 Score	DIT2-N2	NA	0.567
Identity	Commitment to Social Justice		CSJ	7	0.802
	Academic Identity Scale		AIS	7	0.771
	School and Peer Attachment		SPA	14	0.929
End-of-Year Course Objectives Survey (Post-test only)	Intention & Satisfaction Instrument *	Intention	ISI-Int	4	0.784
		Satisfaction	ISI – Sat	4	0.767
	Measure of Classroom Moral Practices	Pro-Social Interactions	MCMP-PI	5	0.808
		Classroom Interactions	MCMP-CI	3	0.705
		Service Project Interactions	MCMP-SI	3	0.784
		Negative Interactions	MCMP-NI	3	0.783
	Multicultural Awareness Scale	Multicultural Understanding	MCAS-MU	6	0.931
		Service Experience	MCAS-SE	4	0.823

A similar approach was taken with regards to students' motivation. However, in this case, three previously validated instruments were available for use. Cacioppo's Need for Cognition Scale (NCS)[10] is an 18 item questionnaire intended to assess "the tendency for an individual to engage in and enjoy thinking".[11] In this sense, the NCS can be seen as a general orientation to be motivated by activities which require considerable cognitive effort. The second instrument, the Situational Intrinsic Motivation Scale (SIMS),[12] represents a situation-based measure of an individual's motivational state. It is designed to be a brief, self-report measure of four distinct facets of motivation: intrinsic motivation, identified regulation, external regulation, and amotivation. Finally, given that during service learning projects students often encounter emotionally charged situations, the Interpersonal Reflectivity Index (IRI)[13] was used to capture the influence of these experiences on students' motivation to act in socially responsible ways. The IRI measures an individual's tendency to take the perspectives of other actors into account and to experience empathy for their condition. All sub-scales use a Likert-type scale and were established using confirmatory factor analysis. Table 2 provides the number of items in each sub-scale and the resulting internal reliability scores.

To assess moral reasoning, we used a single instrument the Defining Issues Test – 2 developed by James Rest and colleagues.[14] The DIT-2 is a multiple-choice test that is based on Kohlberg's Theory of Moral Development[15] and provides a measure of an individual's moral reasoning from a social justice perspective. Of the numerous indices and scores available from the DIT-2, we focus here on the N2 score. The N2 score provides an indication of the extent to which an individual uses principled reasoning in their moral decision making and avoids the use of pre-conventional, self-interested reasoning. Higher N2 scores reflect an individual's increased capacity for reasoning about moral issues based on a system of fairness that serves the public good; lower N2 scores tend to reflect reasoning about moral issues from a self-serving understanding of fairness.

To assess student identity, we used three different instruments: CSJ, AIS and SPA. The Commitment to Social Justice (CSJ) instrument incorporates items that reflect the importance students place on volunteering, promoting racial awareness, and working to better the environment.[16] Consequently, this instrument serves to capture changes in students' attitudes about their role as socially responsible engineers. The Academic Identity Scale (AIS) is an attempt by the authors to capture students attitudes toward their chosen field of study and the extent to which they participate in activities related to their discipline. We were unable to identify any such instrument in the extant literature and, therefore, created an instrument based on conversations with more senior students about what made them feel they were a part of their discipline. Finally, the School and Peer Attachment (SPA) instrument is a compilation of items from two related instruments developed by other researchers.[17,18] It is intended to measure students' beliefs of belonging to a department and the extent to which they feel safe and welcomed among their peers. Each of these instruments uses a 5-point Likert-type scale and was established using confirmatory factor analysis. Table 2 includes the number of items in each sub-scale and the resulting internal reliability scores.

The above instruments were presented to the students in the first-year course sequence at the beginning of the year and again at the conclusion of the service learning project. However, an additional set of instruments was selected for use only at the conclusion of the year. Collectively these instruments were referred to as the End-of-Year Course Objectives survey. These instruments capture students' attitudes toward their experiences in the course sequence, their satisfaction with the course sequence, and their intention to continue their studies in Materials Engineering. The Intention and Satisfaction Instrument (ISI) was developed by the authors as a specific measure of students' satisfaction with their experience in the department during the past year as well as their intention to continue their studies in Materials Engineering. Both sub-scales were established using confirmatory factor analysis. The Measure of Classroom Moral Practices (MCMP) instrument[19] was devised "to assess student attitudes toward and perceptions of educational practices most conducive to facilitating the development of moral reasoning and social justice learning in a classroom context".[20] The original instrument contained three sub-scales, but we failed to confirm these scales and instead found four sub-scales, listed in Table 2, through exploratory factor analysis. Finally, the Multicultural Awareness Scale (MAS) is a ten-item scale that ascertains students' self-reported gains in their level of understanding and awareness of multicultural issues.[21] Again, we failed to confirm the single scale suggested by the developers and instead established two sub-scales via factor analysis. All sub-scales for the

MCMP and MCAS were measured via a 5-point Likert-type scale. Table 2 presents the number of items in each sub-scale and the resulting internal reliability scores.

Sample Description and Study Methodology

Our sample consisted of first-year students enrolled in the introduction to materials engineering design sequence (MATE 110, 120 and 130) at Cal Poly. We did not include a comparison group in the present study. Finding a suitable comparison group with similar demographics and first-year experiences proved difficult prior to the beginning of the academic year. In future iterations of this research, we hope to include multiple control groups with different levels of first-year design experiences.

A total of 52 students enrolled in the Fall quarter (MATE 110) and 43 enrolled in the Spring quarter (MATE 130). A total of 36 students completed both the Fall and Spring round of assessments and are included in the data set presented here. Of this group, there were 28 male (77.8%) and 8 female (22.2%) students. The average age of students was 18.1 years in Fall and 18.8 years in Spring, with a range of 17 to 21 years. Though race and ethnicity data were not collected for this study, we do know that all students were U.S. citizens and spoke English as their first language. Because of the small number of women in the study, and the narrow range of ages, comparison of scales by sex and correlations with age will not be reported.

Prior to administering any of the instruments in the courses, we obtained human subjects approval through the Internal Review Board at Cal Poly. Students were asked to use the last 5-digits of their social security code on their surveys. This approach maintained the confidentiality of the respondents, but also allowed us to match pre- and post-test results. During the second week of classes in the Fall quarter, students were given all of the instruments in Table 2 to complete except the End-of-Year Course Objectives Survey. During the last two weeks of the academic year, students complete all of the instruments listed in Table 2. Following the second administration all student responses were entered into SPSS for further analysis.

Results

Changes in Psychological Constructs during First-year Course Sequence

To determine the impact of the first-year course sequence on the psychological constructs identified in Table 1, we compared data from Fall 2008 and Spring 2009 using paired sample t-tests. The results of this analysis are shown in Table 3. Of the 16 constructs for which we had pre- and post-test data, ten were found to have changed significantly. We found that students' reported shifts in self-efficacy were the most dramatic changes measured. All three of the design self-efficacy sub-scales (DSE-DP, DSE-DT, DSE-DC) were found to change significantly with moderate pooled effect sizes[22] suggesting that the students perceived greater capacity to apply the design process, utilize design tools, and communicate design solutions. We also observed significant changes in students' learning self-efficacy sub-scale scores; however, the effect sizes for these changes were slightly smaller than for design self-efficacy.

Table 3: Changes in Psychological Constructs following First-year Design Sequence

Sub-Scale	t	p	Effect Size
DSE-DP	7.984	<0.001	0.59
DSE-DT	7.651	<0.001	0.51
DSE-DC	8.571	<0.001	0.59
LSE-LL	5.701	<0.001	0.36
LSE-SM	5.148	<0.001	0.41
NCS	0.225	0.823	
IRI-EC	0.443	0.667	
IRI-PT	-1.445	0.157	

Sub-Scale	t	p	Effect Size
SIMS-IM	-2.527	0.016	-0.22
SIMS-IR	-1.974	0.056	
SIMS-ER	5.954	<0.001	0.38
SIMS-AM	3.369	<0.001	0.34
DIT2-N2	2.085	0.045	0.17
CSJ	0.559	0.579	
AIS	1.208	0.235	
SPA	4.512	<0.001	0.36

Results for the motivation sub-scales were far less positive, however. There were no significant changes for the Need for Cognition Scale (NCS) or either of the two Interpersonal Reflectivity Indices (IRI-EC and IRI-PT). The lack of change in the NCS score suggests there was no shift in students' desire to learn new material, even though they felt more confident in doing so as evidenced by the changes in learning self-efficacy. Nor did we observe a change in students' emotional motivation through empathic concern or perspective taking. We did, however, observe statistical differences in students' scores on the Situational Intrinsic Motivation Scale. Unfortunately, the changes were in the opposite direction of what we had hoped. Overall, students reported a small but significant decrease in their intrinsic motivation (SIMS-IM), and small but significant increases in both external regulation (SIMS-ER) and amotivation (SIMS-AM).

Taken together, these results suggest that the class as a whole was less likely to learn out of pure curiosity, and more likely to be apathetic toward learning and see it merely as something they had to do. Although the effect sizes for these changes are small, this is a disturbing trend. It is worth noting, however, that students in the course were broken up into one of six team projects. Students' experiences on these projects were not uniform, and some projects would be considered far more successful than others from both the learner's and instructor's points of view. Though we are not able to track specific survey data back to individual respondents, we suspect that changes in these motivation scores are likely to be highly correlated to the perceived success of the projects.

We did note a small positive gain in moral reasoning score (DIT2-N2), suggesting that students were using principled reasoning more often and personal interest reasoning less often at the conclusion of the course. We note that while the observed gain is relatively small as illustrated by the value of the effect size shown in Table 3, this gain is approximately equal to the shift that is typically observed for students after all four years of college.[23]

Among the identity sub-scales we did observe a positive change in students' relatedness to their school and peers (SPA). Again, the effect size of 0.36 could be considered relatively small. We did not, however, observe any change in students' commitment to social justice (CSJ) as an important aspect of their identity. Nor did we notice any shift with regards to their personal sense of attachment to their discipline (AIS).

Correlations between Significant Changes in Psychological Constructs

As previously described, we observed a number of significant changes in students' reported sub-scale scores from Fall 2008 (pre-test) to Spring 2009 (post-test). We further examined possible relationships among these observed changes using Pearson's bivariate correlations. Here we present only those sub-scales for which a significant change was observed. For each of the sub-scales with significant changes, we calculated a change scale by subtracting the Fall 2008 score from the Spring 2009 scale. The correlation values shown in Table 4, therefore, are the correlations between the computed changes for each sub-scale. Only significant correlations are shown in the table.

Not surprisingly the various design self-efficacy scores are highly correlated to one another. Given that all of these scales are focused on students' self-perceptions about their design abilities, we would expect to observe some degree of multi-collinearity among these variables. The most notable correlation is between students' perceived gains in their ability to apply the design process (DSE-DP) and their ability to communicate design solutions (DSE-DC). Interestingly, self-efficacy toward design tools (DSE-DT) such as CAD was less strongly correlated with the other design self-efficacy sub-scales.

Table 4: Significant correlations between pre-/post-change for sub-scales with significance differences from Fall (pre-) to Spring (post-)

	DSE-DP	DSE-DT	DSE-DC	LSE-LL	LSE-SM	SIMS-IM	SIMS-ER	SIMS-AM	DIT2-N2	SPA
DSE-DP	-									
DSE-DT	0.59**	-								
DSE-DC	0.70**	0.52**	-							
LSE-LL	0.38**	-	-	-						
LSE-SM	0.84**	0.58**	0.42*	0.51**	-					
SIMS-IM	-	-	-	-	-	-				
SIMS-ER	-	-	-	-	-	-	-			
SIMS-AM	-	-	-	-	-	-0.51**	-	-		
DIT2-N2	-	-	-	-	-	-	-	-	-	
SPA	0.56**	-	-	-	0.54**	0.35*	-	-	-	-

* $p<0.05$, ** $p<0.01$

We also found that reported shifts in the learning self-efficacy sub-scales were highly correlated to one another. Not surprisingly, students who felt better able to monitor their own learning (LSE-LL) following the course sequence, also felt more confidence in applying science and mathematics principles to engineering (LSE-SM). We also found that gains in learning self-efficacy were correlated to increases in design self-efficacy, particularly application of science and math principles.

Among the motivation sub-scales, the only correlation found was a negative correlation between gains in intrinsic motivation (SIMS-IM) and reductions in amotivation (SIMS-AM). This result is expected. It is generally held in motivation theory that amotivation is the absence of either intrinsic or extrinsic motivation, thus these scores should be inversely related to one another. We did not observe a significant correlation between changes in intrinsic motivation and external regulation (SIMS-ER). For the students in this course, these two sources of motivation act independently of one another. In other words, even though students may feel more or less willing to engage in learning out of an inherent curiosity and joyfulness, they may feel equally motivated to learn for the sake of an external reinforcement such as a grade.

Lastly, we measured significant positive correlations between gains in students' sense of relatedness with their discipline (SPA) and gains in several other sub-scales, including self-efficacy with the design process, self-efficacy with the application of science and math, and intrinsic motivation. This is a fascinating finding because it supports the general assumption that students who report greater gains and interest in design, science, and mathematics are more likely to identify with their discipline, in this case materials engineering.

Correlations between End-of-Year Course Objectives Sub-scales

Using the Intentions and Satisfaction Instrument, we can arrive at an estimate of students' satisfaction with the course and their intention to continue in the program. Each of these sub-scales is based on four items and so we do not present the results of each question here. However, by taking the average response to all four questions, we can derive a composite measure of satisfaction and intention for each student. Based on this approach we can conclude that 77.5% of the students in the class were on average satisfied or very satisfied with the course and 85% intended to continue within the Materials Engineering Program, while 12.5% indicated they were unsure and 2.5% did not intend to continue. While these numbers are encouraging, the reader is reminded that of the 52 students in the sample at the beginning of the first-year design experience, only 43 completed the full year of courses, and only 36 completed both pre- and post-test surveys. We were not able to track the 9 students who left the sequence during the year.

When comparing students' reported scores on the various retention and satisfaction sub-scales, we found a number of significant correlations as shown in Table 5. Perhaps most importantly, students' intention to continue studying materials engineering (ISI-Int) was positively correlated with their satisfaction with their first-year experience (ISI-Sat). Intention was also correlated moderately to the quality of students' classroom interactions (MCMP-CI) during the year. Here we define quality as the extent to which students were encouraged to participate in active learning and classroom discussions.

Table 5: Significant correlations between retention and satisfaction sub-scales

	ISI-Int	ISI-Sat	MCMP-PI	MCMP-CI	MCMP-SI	MCMP-NI	MCAS-MU	MCAS-SE
ISI-Int	-							
ISI – Sat	0.43**	-						
MCMP-PI	-	0.47**	-					
MCMP-CI	0.41**	0.54**	0.44**	-				
MCMP-SI	-	-	-	0.33*	-			
MCMP-NI	-	-0.47**	-	-	-0.39*	-		
MCAS-MU	-	0.54**	0.80**	0.50**	0.46**	-	-	
MCAS-SE		0.66**	0.48**	0.55**	0.49**	-0.34*	0.56**	-

* $p<0.05$, ** $p<0.01$

With regards to students' self-reported satisfaction with their first-year experience, we observed quite a few significant correlations. Students who reported a greater sense of satisfaction with the sequence were also more likely to report participating in pro-social interactions (MCMP-PI) and interactive classroom interactions during the year. Not surprisingly, more satisfied students were less likely to report having had negative interactions (MCMP-NI) with their peers. Satisfaction was also correlated with students' perceived gains in multicultural awareness. In particular, students' who reported developing a greater awareness of the issues faced by particular cultural groups (MCAS-MU) and gaining experience working on issues important to a community (MCAS-SE) were more likely to report feeling satisfied with the first-year experience.

We also noted a number of moderate positive correlations between sub-scales of the Measure of Classroom Moral Practices (MCMP) and the Multicultural Awareness Scale (MCAS) suggesting that the extent to which students experience pro-social and positive interactions during the first-year may be related to their perceived gains in their awareness of and experience with multicultural issues.

Finally, we examined correlations between the intention and satisfaction sub-scales and the various sub-scales measuring changes in self-efficacy, motivation, identity and moral reasoning. As shown in Table 6, gains in self-efficacy were, in general, not correlated to either students' intention to continue within the Materials Engineering program or their satisfaction with the first-year course sequence. The one exception is the weak correlation between students' reported gains in their confidence in applying science and math principles to engineering and their intention to continue in the program. For this study, at least, gains in self-efficacy seem unrelated to matters of student retention and satisfaction.

Table 6: Significant correlations between intention and satisfaction sub-scales and sub-scale changes with significance differences from Fall (pre-) to Spring (post-)

	ISI-Int	ISI-Sat
DSE-DP	-	-
DSE-DT	-	-
DSE-DC	-	-
LSE-LL	-	-
LSE-SM	0.38*	-
SIMS-IM	-	0.59**
SIMS-ER	-	-
SIMS-AM	-	-0.39*
DIT2-N2	-	-
SPA	0.39*	0.33*

Likewise, we observed no correlation between students' reported changes in their motivation and their intention to continue studying Materials Engineering. This seems odd considering that one would expect that those students who developed a deeper personal desire to study Materials Engineering (SIMS-IM) would be more likely to intend to continue studying the subject. However, we did find that students' satisfaction with the first-year sequence was related to their motivation scores, with satisfaction being positively correlated with gains in intrinsic motivation and negatively correlated with gains in amotivation. Motivation scores are known to be highly dependent on the context in which they are assessed. So it may be that when students were asked to comment on their satisfaction in the course, they made reference to concrete positive and negative experiences during the past year; whereas, when asked to indicate their intention to continue their studies, they made reference to their more abstract uncertainties about the remainder of the curriculum. This uncertainty and anxiety may overwhelm any sense of inherent interest they developed in the first-year.

We take solace, however, in the fact that both intention and satisfaction were positively correlated to students' perceived attachment to their discipline (SPA) if only weakly. Though it is only anecdotal, we have continued to struggle to help our students develop an identity as a materials engineer. This is due primarily to the fact that the field is highly multi-disciplinary and thus has no clear definition in the same sense that aerospace or civil engineering does. Thus, we take these correlations as a positive sign that our efforts in the first-year sequence to encourage students to identify with the discipline and the department are having an impact.

Regression Analyses of Intention and Satisfaction Sub-scales

We completed a step-wise linear regression analysis with students' intention to continue within the Materials Engineering program (ISI-Int) as the dependent variable. Input variables included those psychological constructs found to change significantly from Fall 2008 to Spring 2009, as well as those psychological constructs and end-of-course objectives sub-scales found to correlate with the dependent variable. Input variables were included in the model if a significance level of 0.05 or better was met for the standardized regression coefficient. The results of the regression analysis are provided in Table 7. The final model explained 31.8% (R^2) of the variance and was significant at the p=0.003 level.

Results indicate that students' satisfaction with the first-year experience was the strongest predictor of their intention to continue within the program. This is not surprising given the lack of variability in the intention scale. We also observed that students' sense of self-efficacy with regard to applying science and mathematics principles to engineering was a predictor of their intention to continue in the program. Interestingly, the quality of their classroom experiences and the strength of their attachment to their peers or the discipline were not predictive.

Table 7: Regression results for student intention scale

Model Variables		t	Standardized Coefficients
Scale	Sub-Scales		β
Intentions and Satisfaction Scale	*ISI-Sat*	2.799	0.425**
Moral Classroom Practices	*MCMP-CI*	0.743	0.138
Learning Self-Efficacy Scale	*LSE-SM*	2.105	0.320*
School and Peer Attachment	*SPA*	0.020	0.004

* p<0.05, ** p<0.01, *** p<0.001

Given the strength of satisfaction on predicting a students' intention to remain in the Materials Engineering program, we completed a subsequent regression analysis with students' reported satisfaction with the first-year experience (ISI-Sat) as the dependent variable. Again, input variables included those psychological constructs found to change significantly from Fall 2008 to Spring 2009 and to have been significantly correlated with the dependent variable, as well as end-of-course objectives sub-scales found to correlate with satisfaction. The results of the regression analysis are provided in Table 8. The final model explained 68.8% (R^2) of the variance and was significant at the $p<0.001$ level.

Based on the results, the most significant predictor of students' satisfaction with the first-year experience is their perceived gain in intrinsic motivation (SIMS-IM). We also found that the interactive nature of the classroom (MCMP-CI) and experiences in dealing with community issues (MCAS-SE) were significant predictors of satisfaction. After accounting for these input variables, the other correlates failed to be significant predictors. Ultimately, the interactive nature of the classroom was more important to students' satisfaction than pro-social interactions (MCMP-PI) and negative interactions (MCMP-NI), experiences with community issues were more important than multicultural understanding (MCAS-MU), and gains in intrinsic motivation were more important than changes in amotivation (SIMS-AM). We also noted that attachment to the discipline (SPA) also failed to predict student satisfaction.

Table 8: Regression results for student satisfaction scale

Model Variables		t	Standardized Coefficients
Scale	Sub-Scales		β
Moral Classroom Practices	*MCMP-PI*	-0.124	-0.017
	MCMP-CI	2.381	0.314*
	MCMP-NI	-1.550	-0.182
Multicultural Awareness Scale	*MCAS-MU*	0.078	0.012
	MCAS-SE	2.103	0.306*
Situated Intrinsic Motivation Scale	*SIMS-IM*	3.575	0.436***
	SIMS-AM	-0.344	-0.044
School and Peer Attachment	*SPA*	0.515	0.062

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Conclusions

Before discussing the implications of this work, we should first point out the limitations. First, this research was conducted without a control or comparison group due to an inability to find a group with similar demographics and the challenge of identifying one group of students who had a first-year experience similar in every way to the students in this study. Consequently, we are unable to make any absolute claims about the first-year design experience being the source of the observations presented in this paper. Second, the sample size for this study was small and lacked sufficient representation from sub-groups such as women and minorities, making generalizations to other student bodies tenuous. The small sample also raises questions about the use of factor analysis for scale creation, and further work is needed before these scales can be formalized.

Third, while we used validated instruments to measure the impacts of interest, this was not always possible. More work is needed to validate the instruments we crafted, and some likely need to be modified based on this preliminary study. Fourth, our study design did not permit us to disaggregate student responses by project team for confidentiality reasons. We cannot, therefore, determine if students involved in a "successful" project team scored any differently from those that were involved in less successful teams. This is an area that will need to be considered carefully in subsequent iterations of this research. Lastly, because we were not able to follow up with students who did not complete the entire three quarter course sequence, we can only speak to those factors that influenced the intentions of students who remained in the department.

Perhaps the most robust finding of this study was that participants reported a significant and moderately large increase in their design self-efficacy. Students reported feeling more confident in their ability to use a design process, use design tools, and communicate design results to others. We suspect this change is in fact due to the design sequence described in this paper, since this was the only design experience these first-year students would have during that time. We cannot absolutely attribute this change to the service learning portion of the course, since students did carry out design projects outside the service learning experience. However, based on anecdotal evidence, the addition of a service learning component provided the necessary motivation and context which led to deeper learning than had previously been available. We also observed smaller, but significant changes in students' moral reasoning, school and peer attachment and learning self-efficacy. It is difficult to attribute these changes specifically to the first-year design experience.

With regard to retention of students, we are pleased to see that of those students who completed the three quarter sequence, the overwhelming majority of students intend to continue their studies in the Materials Engineering Department. For these students, it seems that their satisfaction with the course and their self-efficacy with regards to the application of basic science and mathematics principles were most influential on their intention to continue in the program. Satisfaction, in turn, seems most strongly influenced by the quality of students' classroom experiences in the first-year design course and the extent to which they increased their intrinsic motivation with regard to engineering. We believe that the focus on an active learning approach to the classroom, and providing as much one-on-one interaction between the instructors and students is paying off. We also note that despite the influence of intrinsic motivation as a predictor of students' intention to continue in the program, the average level of intrinsic motivation in the course actually decreased. Given that the majority of students were satisfied with the course, the decrease in intrinsic motivation is likely due to a few unsatisfied students who had very large decreases in motivation. Overall, we believe that these data point to the success of service learning as a pedagogy for enhancing out students' experience within the curriculum.

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APPENDIX: Unpublished instruments

Design Self-Efficacy

Instructions: For each of the statements below, please indicate how sure you are that you can complete the tasks identified in the statement. Please circle the appropriate response using the following scale. **Do not circle more than one number.**

1=Completely unsure
2=Somewhat unsure
3=Neither sure nor unsure
4=Somewhat sure
5=Completely sure

1.	Correctly complete a needs assessment associated with a client or market	1	2	3	4	5
2.	Draw isometric views of a simple three dimensional object	1	2	3	4	5
3.	Write a technical memo	1	2	3	4	5
4.	Correctly identify a problem to be solved and the requirements that must be met to solve that problem	1	2	3	4	5
5.	Make a three dimensional sketch of a simple object form isometric views	1	2	3	4	5
6.	Convey the results of an engineering project through a technical presentation or design review	1	2	3	4	5
7.	Come up with creative engineering solutions to a design problem	1	2	3	4	5
8.	Put dimensions on an engineering drawing of a simple object	1	2	3	4	5
9.	Write a technical report to summarize the results of an engineering project for a supervisor	1	2	3	4	5
10.	Compare several engineering solutions to determine which is likely to provide the best possible solution for a client or market	1	2	3	4	5
11.	Using an engineering drawing, <u>determine</u> an appropriate method of fabricating an object	1	2	3	4	5
12.	Write an agenda for a design review meeting	1	2	3	4	5
13.	Test and analyze prototypes of an engineering design	1	2	3	4	5
14.	Successfully <u>fabricate</u> an engineering design using appropriate equipment and an engineering drawing	1	2	3	4	5
15.	Discuss progress or problems during an informal design review with an engineering project supervisor	1	2	3	4	5
16.	Determine whether a completed engineering design actually meets the needs of a client or market	1	2	3	4	5

Scoring:
Design Process: Sum Items 1, 4, 7, 10, 13, 16
Design Tools: Sum Items 2, 5, 8, 11, 14
Design Communication: Sum Items 3, 6, 9, 12, 15

Learning Self-Efficacy

Instructions: For each of the statements below, please indicate how sure you are that you can complete the tasks identified in the statement. Please circle the appropriate response using the following scale. **Do not circle more than one number.**

1=Completely unsure
2=Somewhat unsure
3=Neither sure nor unsure
4=Somewhat sure
5=Completely sure

1.	I can identify shortcomings in my knowledge and skills	1	2	3	4	5
2.	I can apply chemistry concepts to the design of an engineering solution	1	2	3	4	5
3.	I can easily identify sources of information to support learning a new subject	1	2	3	4	5
4.	I can apply mathematics to the design of an engineering solution	1	2	3	4	5
5.	I can learn new knowledge and skills on my own	1	2	3	4	5
6.	I can apply physics concepts to the design of an engineering solution	1	2	3	4	5
7.	I can learn new material regardless of the form in which it is presented	1	2	3	4	5
8.	I can recognize when an engineering problem might require application of a concept from math, physics, or chemistry	1	2	3	4	5
9.	I can make my own decisions about what I should be learning in order to meet my goals for the future	1	2	3	4	5
10.	I can recognize when test data from an engineering solution does not appear to agree with mathematics, physics, or chemistry concepts	1	2	3	4	5

Scoring:
Lifelong Learning: Sum Items 1, 3, 5, 7, 9
Integration of Math and Science: Sum Items 2, 4, 6, 8, 10

Intentions and Satisfaction Scale

Instructions: For each of the statements below, please indicate to what extent to which you agree with the statement. Please circle the appropriate response using the following scale. **Do not circle more than one number.**

1=strongly disagree
2=disagree
3=uncertain
4=agree
5=strongly agree

17.	My experience in the Materials Engineering program this past year has been very positive.	1	2	3	4	5
18.	I plan to continue pursuing my materials engineering degree.	1	2	3	4	5
19.	I've become very unhappy with the Materials Engineering program this year.	1	2	3	4	5
20.	I will probably change majors soon.	1	2	3	4	5
21.	Overall, I'm very satisfied with my experience in the Materials Engineering program.	1	2	3	4	5
22.	I intend to register for courses in the MATE department next year.	1	2	3	4	5
23.	I'm excited about taking more MATE courses.	1	2	3	4	5
24.	I really don't know whether I'll continue in the MATE department next year.	1	2	3	4	5

Scoring:
Reversed Items: 3, 4, 8
Satisfaction scale: Items 1, 3, 5, 7
Intention Scale: Items 2, 4, 6, 8