Learning from Experiences: Examining Self-Reflection in Engineering Design Courses

Jennifer Wegner, University of Michigan College of Engineering

Jennifer Wegner is an Assistant Director in Engineering Student Affairs at the University of Michigan, with responsibilities including student organization development, leading unit strategic objectives, and supporting university and college co-curricular initiatives. Her teaching and facilitation experiences include a mentorship/leadership course, LeaderShape®, first year seminars, and a university course on social psychology in residence settings. She is a member of the NASPA Center for Women National Board and co-founded the University of Michigan Women in Student Affairs chapter. Jennifer's research interests include the culture of busy, the intersection of women's higher education career ascension and professional development, and women's leadership development. She is currently a doctoral student at New England College and holds her M.Ed. in Higher Education Student Affairs from the University of Vermont and a B.A from Oakland University.

Mr. Stefan M Turcic II, University of Michigan

Stefan Turcic is a recent graduate from the University of Michigan in Ann Arbor, MI, where he received his M.A. in Higher Education from the Center for the Study of Higher and Postsecondary Education. He is an Educational Research Assistant and Program Assistant for the Multidisciplinary Design Program in the College of Engineering at the University of Michigan. His research interests include teaching and learning environments, student involvement, higher education management and organizations, and institutional assessment. He also holds a B.S. from Benedictine University in Lisle, IL.

Ms. Gail Hohner, University of Michigan

Gail Hohner is the Managing Director of the Multidisciplinary Design Program in the College of Engineering at the University of Michigan Ann Arbor, where she develops multidisciplinary engaged learning experiences in the engineering design process. She teaches the seminar in Leadership/Mentorship in Multidisciplinary Engineering Design and her research focuses on the improvements in the pedagogy of engineering design process instruction. She is the 2016 program chair of the DEED division of ASEE. She has a background of 17 years of industrial experience and holds B.S.E in Chemical Engineering and a M.S. in Food Science/Chemical Engineering from Cornell.

Learning from Experiences:
Examining Self-Reflections in Engineering Design Courses

Abstract

This work assessed student reflective learning outcomes during a final Leadership/Mentorship course, after their participation in significant, experiential design projects in the University of Michigan's Multidisciplinary Design Program in the College of Engineering. Throughout the course, class discussions and assignments prompted students to reflect and examine their personal experiences in engineering design projects, their learning (both technical and professional), leadership, and team styles as well as understand group development and dynamics.

A feature of the projects was the integration of students from diverse disciplines in engineering with other programs such as: Art, Architecture, Primary Sciences, Kinesiology, and Business. The diverse teams provided a rich environment but also created the complexity of multiple paradigms within the project teams. This course utilized the construct of Kolb's Experiential Learning Model[1] and Kavanagh's reflection exercises[2] to promote active reflection on students' team based engineering design project experiences. The in-class discussions and self-reflection based assignments not only helped students to more fully understand the technical aspects of engineering design, but also contributed to a greater understanding of working as a team and as competent, adaptive professionals.

In a final reflection assignment, students described self-identified critical moments/milestones in their development (i.e., including design projects, classes, extracurricular activities, employment, etc.) and how the experience gained from those moments is important to their development as practicing professionals, effective mentors, and strong leaders. From these milestones, we identified common themes and experiences, including the impact on students' cognitive and professional identity development.

Milestones were identified based on the forum for the experience such as classroom coursework, university-sponsored projects, extracurricular activities, student mentorship, and internship experiences. In addition, we examined each milestone to determine the types of skills/learning and professional competencies students identified as a result of each experience. The results offer a fascinating snapshot of how and where students recognize and value the development of these skills.

We saw several themes emerge in the data. Although students identified a range of learning opportunities, the most common milestones originated from students' courses, extracurricular activities, mentorship opportunities, and team projects. From these milestones, we found a variety of professional skills and competencies identified as significant by the students: communication skills, navigating group dynamics, and planning/organization abilities are most prominent. Finally, we noticed differences in the proportions of milestones and skills when analyzing other factors such as: sex, grade point average, citizenship status, minority identity, and underrepresented minority status. The results are being utilized to strengthen how we teach engineering design and enhance engineering pedagogy for others.

Introduction

Context

The Multidisciplinary Design Program (MDP) provides students from across the University of Michigan an opportunity to develop and refine their engineering skills by working on significant, open ended, team-based engineering design. The program's educational goals are to produce students (1) possessing deep technical skills and the ability to be systems thinkers; (2) capable and skilled in bringing creativity and innovation to design and problem-solving; (3) who are independent learners, able to reinvest themselves throughout their careers; and (4) who are effective communicators and team players in their professional and personal lives.

MDP offers a course sequence titled Multidisciplinary Engineering Design (Intro, Intermediate, Advanced) each of which may be repeated multiple times as students develop their skill sets, both technical and professional. Currently over 400 students participate in at least one semester of this course sequence each year. The program also offers an academic minor at the undergraduate level. The minor requires four elements: (1) an Introductory Design Experience (1 semester); (2) a major design project (2 or more semesters); (3) a cornerstone course (supporting knowledge and skills related to the individual's major design project); and (4) a Leadership/Mentorship Seminar. Roughly 100 participate in the academic minor each year.

The goal of the course, titled *ENGR 456: Mentorship-Leadership in Multidisciplinary Design*, was to promote reflective learning based on past engineering design experiences as well as develop needed professional competencies that will be used in their future jobs. During the course, students used writing assignments to practice reflection skills. Data from four semesters: Fall 2012, Winter 2013, Fall 2014, and Winter 2014 were included in the scope of this project.

To assess the effectiveness of these courses, in regards to reflection skills and professional competencies, data from students' final reflection papers were collected and analyzed around guiding research questions. We wanted to see which milestones students described and reflected upon as influential to themselves. Are there certain types of milestones that students identified as important? What similarities and differences are present when compared against sex, GPA, minority identity etc.?

From these milestones, we wanted to see what type of skills arise from their milestones. Do students gain or utilize a wide range of professional skills from their milestones? What similarities or differences are present when comparing against other groups?

In addition, we sought to better understand how the reflective process affects student development, as well as use the results to consider the benefits of including experiential learning and reflection in the format of this assignment in engineering courses.

Literature Review

Experiential Learning

Though lectures are perhaps the most prevalent way to teach students, they contribute to a passive form of learning and are not conducive to active learning. Lectures are commonly teacher-centered systems where the priority of the classroom dynamic is the teacher, not the student. A recent study found that undergraduate STEM students are about 1.5 times more likely to fail a class in a teacher-centered lecture format compared to classes with more active learning strategies.[3] Experiential learning is a form of active learning, and its components can complement what is learned in lecture, which can typically promote understanding. Engineering design is almost always taught via experiential, project-based learning.

Several researchers have developed various experiential learning theories including early works of John Dewey, Jean Piaget, Kurt Lewin, and David Kolb. The early theory of John Dewey described a model of experiential learning demonstrating that learning occurs in a feedback loop.[4] The experiential feedback loop involves: observations of an experience, knowledge of similar situations, and the judgment to create meaning and positive changes from their experience.

Perhaps the most popular and widely recognized model for experiential learning is from David Kolb.[1] Kolb's model offered a holistic perspective on learning by combining experience, perception, cognition, and behavior.[1] For this model to be successful the learner must: actively be involved in that experience (concrete experience), reflect on that experience (reflective observation), conceptualize the experience (abstract conceptualization), and apply what was learned to new experiences (active experimentation).[1]

Experiential learning is a component of education that "emphasize[s] the central role that experience play in the learning process."[1] As explained by Hey, Van Pelt, Agogino, and Beckman, some areas, such as practical and teamwork skills that are important in engineering design education, are best taught through experience instead of through formal lectures.[5]

In that regard, experiential learning has many benefits including development of "professional skills" not commonly given attention to in engineering pedagogy, in favor of the "hard skills" needed in STEM disciplines.[6] In addition, development of skills is best facilitated through students' practice and experiences.[7, 8, 9] Experiential learning also promotes greater knowledge retention, improves critical thinking and writing skills, and motivates students.[10, 11] Similarly, the Davis et al. study found in their research that experiential learning did improve comprehension, leadership qualities, and confidence in students in a construction management course.[11]

The Sheppard report sponsored by the Carnegie Foundation examined the practices and pedagogies of over 1,000 engineering programs in the United States.[12] A main takeaway from this report highlighted the need for experiential learning in engineering pedagogy as a way to better prepare future engineers: "If engineering students are to be prepared to meet the challenges of today and tomorrow, the center of their education should be professional practice, integrating technical knowledge and skills of practice through a consistent focus on developing the identity and commitment of the professional engineer."[12]

Engineering education is a very technical and methodological pedagogy. However, experiential learning is an effective way to teach and practice professional skills.[13] In engineering courses, experiential learning can promote lifelong learning, a common goal for many higher education institutions.[6] The research also found that professional skills are best cultivated and enhanced by practicing them through real experiences.[6] Davis et al. also stated that it is difficult for students to achieve leadership skills in a lecture format.[11]

Reflection

Expanding on the experiential learning theories, reflection is an increasingly important element that must be discussed in student learning. Self-reflection is a way to bridge connections between elements of specific experiences and contributes to true learning and positive changes.[4] Similarly, Wong et al. stated that reflection integrates theory with practice and appreciation of the world.[14] This parallels Hey et al. who stated that reflection is a tool that assists students in applying knowledge to practice.[5] Schon described reflection as a "critical tool" for a reflective practitioner in the practical and technical sense in engineering education.[15] The development of "soft" professional skills and "hard" technical skills is essential for a successful career and should be acknowledged in a student's education to create a foundation upon which the student can grow.[13]

Studies have shown that having an experience is not enough for understanding and application of knowledge,[14] but adding reflection can contribute immensely to student learning. Socha et al. also described five types of skills for effective engineers: reflective skills to contribute to lifelong learning, team skills to work well with others, project skills to navigate projects to a successful outcome, value skills to increase value in each step of a project, and design skills for creating and building good designs.[13] Socha et al. separated and distinguished reflective skills in that they "help one improve in *all* skill domains, whereas the same is not true for the other types of skills."[13]

Socha et al. determined that reflection is needed to complete the learning process, specifically learning from students' experiences and learning from the mistakes that occurred during those experiences, which are vital to the learning process as well.[13] Socha et al. also described reflection as "one of the most effective tools" in lifelong learning and helps our understanding of the world.[13] According to Schon, reflection assisted students in understanding unique situations.[15] Reflection is described as "the metacognitive process of thinking about past action but is usually omitted in engineering courses.[6] Further, reflection is seen as being "beyond knowledge acquisition" and takes learning a step further to promote personal understanding.[16]

Reflection is a technique that is a new and unfamiliar practice for many students in engineering disciplines.[17] Reflection is described as something that is not natural for engineers due to the demanding engineering curricula, where there may little room to include such activities.[18] The importance of reflection in courses is demonstrated in Wong et al. who suggested that student writing can be used as evidence of reflective thinking and learning.[14]

As previously stated, there are several ways to engage in critical reflection. Kavanagh listed end of course meta-learning, portfolio reflections, peer assisted learning sessions in their engineering course,[2] and as seen in O'Moore and Baldock,[19] they discussed online reflections, and team reflections. Each technique has strengths and weaknesses, but they provide a different approach to understanding of learning outcomes and experiences. Journal writing has also been seen in the literature,[13, 14, 17] and in these instances, reflection can occur in the journal entries and student learning can be assessed in these assignments.

In engineering education, Mitchell, Jolly, and McLeod advocated for integrating reflective thought into coursework and state that reflection was "a suitable vehicle for developing advanced problem solving and life-long learning skills." [20]

Reflection is also a technique that contributes "deep learning" in students.[21] Hinett stated that from reflection, learners construct their own meaning to their experiences, and this process used their cognitive skills such as reasoning and knowledge and their metacognitive skills such as intuition and self-awareness.[21] This process helped the students use their prior knowledge and make connections in their metacognitive network of ideas, which is part of the learning process as detailed by Moon.[22] In addition, Meizrow showed that reflection contributes to higher-order thinking and metacognition.[23]

Wong et al. stated that there is a lack of research and assessment in looking at reflective practices in the classroom.[14] Though there are some studies that assess reflection in college students in general[2, 5, 14], the research and assessment specific to reflection exercises in engineering courses is even smaller.

Experiences without the reflective element may put students at a loss in that they may not complete the learning cycle. Meizrow examined the distinction between reflective actions and non-reflective actions from experiences and also examined how experiences can be transformational in nature when the learning cycle is completed with reflection.[23] To engage in critical reflection and transformational education, one must understand and challenge presuppositions from their prior learning. This will result in a transformative experience in a student's cognitive, affective, and conative realms.[23] Reflection also creates meaning making from experiences.[23]

The problem with non-reflective learning is best described by Habermas as missing the last and crucial step of reflection and understanding.[24] That paper noted that non-reflective learning "takes place in action contexts in which implicitly raised theoretical and practical validity claims are naively taken for granted and accepted or rejected without discursive consideration."[23] Meizrow again advocated that the last step in the learning cycle, the reflective action and subsequent meaning making, is needed to create a transformative effect in students' education.[23] These transformative effects can help in an engineer's career by the application of their transformative learning to new projects.[11]

Finally, active self-reflection contributes to student development throughout their college years and can positively contribute to the preparation for their future careers and lives. Critical self-reflection is a vital component of self-authorship, the ability to create an internal foundation and create internal values and decisions in their lives.[25] The external to internal ability to define the self assists in the social and professional development of students.[25]

Context of Course

Program and Course Description

The University of Michigan's Multidisciplinary Design Program was established in 2007. As seen in Conger et al., students were excited to begin their engineering programs at the university, but there was a disconnect from what they learned in their courses to their professional practice after graduation.[26] MDP is but one piece of the university's commitment to prepare engineers for the 21st century and beyond. Recognizing the need for cooperation and collaboration among different disciplines in the design process, a common experience for all engineers, MDP, was created to allow students and teams to work together from their various backgrounds to respond to engineering design projects.

The ENGR 456 course meets five times each semester. It is designed to complement leadership and/or mentorship roles that the students have in their engineering design project teams or other organizations. Leadership exercises and activities allow students to reflect and explore their leadership styles, team styles, group development, evaluation assessments, and leadership approaches. A course goal is for students to enhance individual skills that can be applied immediately to their project teams and organizations. Various learning methods including individual, small group, and large group experiences are included throughout the course. Assignments include pre-class readings and exercises, short reflection papers, and a final milestone reflection assignment.

Course Assignments

Throughout the course, there are several reflection papers with various topics such as discussing leadership styles, developing a culture of leadership, defining their leadership qualities, and considering technical and adaptive challenges in leadership. These shorter reflection papers are designed to assist the students in the process of active reflection on their past experiences. The goal is for students to develop reflective skills, be able to learn from the reflection exercises for future application, and become thoughtful and reflective professionals.

The final writing assignment is a reflection exercise that considers past leadership and mentorship experiences through the students' identification of important milestones and certain themes. Milestones are defined as self-identified critical moments in students' previous leadership and mentorship experiences. Students choose five milestones to reflect upon in this cumulative final assignment, and their milestones can be positive or negative experiences that led to a change or made the students feel like they grew as a leader and/or mentor. To gain a deeper understanding of their experiences, students identified their milestones, described what they learned from the experience, and explained how they will incorporate what they learned in the future.

The assignment was designed in the format of: "What" "So What" and "Now What" for each experience. This format is designed to complement Kolb's Experiential Learning Model.[1] This final reflective assignment makes use of Kolb's Experiential Learning Model as a way for students to process and integrate active reflection in their learning. For the "What" step, students were asked to describe their experiences and their role in each experience, discuss challenges or struggles that arose, and explain the overall result for each experience. The "So What" step asked students if the experience was positive or negative, what was learned from the experience, and why the experience was memorable in their minds. The final step, "Now What," asked students to discuss how the experience led them to approach leadership activities differently and how the experience will shape their approach to future leadership.

Methodology

Before starting this project, we sought approval through the University of Michigan's Institutional Review Board in the summer of 2014. Our study was granted exempt status because the research evaluates a specific course. From here, we sent an email to every student in the classes taught in Fall 2012, Winter 2013, Fall 2013, and Winter 2014 with instruction to opt-out of including their final reflective papers and demographic information in this project. Only three students chose not to participate in the research. A total of 98 students are included in this project.

The final reflection papers were then downloaded from the university's learning management system and were initially reviewed for emerging themes and content. After this process, milestones were coded by the focus of the experience and several categories of milestones were created to assist in the analysis portion of the project. Milestone classifications were based on the types of experiences in relevance to university sponsored and outside sponsored experiences. To ensure accuracy, the coding was reviewed a second time by the researchers. The final categories that we have developed for the milestones are included in Table 1 below.

Table 1: Milestones
Classroom Experiences (19%)
Extracurricular Activities (19%)
Greek Life (2%)
Internships (4%)
Jobs (2%)
Mentorship Experiences (23%)
Projects (University and MDP sponsored) (28%)
Volunteering Experiences (3%)

Table 1: A survey of the milestones that students reflected upon in their final reflection papers. Each student reflected on five milestones. The percentage of the occurrence of each milestone in relation to the total number of milestones reflected upon is presented here.

From this, the final reflection papers were analyzed again, this time looking for professional skills and competencies that were used or gained during their experience with each milestone.

There were a number of professional skills and competencies seen throughout the students' milestones. The categories for the professional skills and competencies are included in Table 2 below.

Table 2: Professional Skills and Competencies	
Accountability (1%)	Listening Abilities (2%)
Adaptability (2%)	Motivating Team/Others (1%)
Conflict Management (5%)	Patience (2%)
Confidence (8%)	Planning/Organization Skills (8%)
Creativity (1%)	Professionalism (16%)
Communication Skills (11%)	Resourcefulness (1%)
Critical Thinking (1%)	Respect for Self/Others (2%)
Data Analysis (1%)	Self-Reflection (3%)
Determination (3%)	Responsibility (2%)
Decision Making (3%)	Self-Awareness of Achievement (3%)
Flexibility (1%)	Society/Ethical-Based Thinking (1%)
Global Awareness (1%)	Technical Abilities/Knowledge (5%)
Group Dynamics Navigation (8%)	Teamwork (2%)
Independence (7%)	Time Management (4%)
Initiative/Self-Motivation (5%)	Trust (1%)
Integrity (1%)	Teaching/Mentoring Skills (6%)
Leadership Skills (8%)	

Table 2: A survey of the professional skills and competencies that students reflected upon in their final reflection papers. These were recorded from the final reflection papers if students had utilized of gained the skills from the milestones. The percentage of the occurrence of each skill in relation to the total number of skills reflected upon is included here.

As stated before, we analyzed the final reflection papers for four terms. Also, we conducted statistical analyses of the data between certain populations to discover any significance of the data. A significant finding from this analysis indicates that the two comparison populations are statistically different from each other.

Results and Analysis

Student Population Demographics

The student demographics of this course reflect broader demographics of the College of Engineering as well as other engineering programs around the United States. For all of the classes, there are approximately 77% male students and 23% female students. Many students in this course are U.S. citizens and identify as white. 81% of the students are U.S. citizens, 16% are non-residents, and 3% are permanent residents. The racial makeup of the student sample is: White students (62%), Asian students (23%), Hispanic students (8%), Black students (2%), and not indicated (4%). With this, 10% of the sample (Black and Hispanic students) are from underrepresented populations. Notably, Asian and Hispanic students are represented in this course at a greater percentage when compared to demographics of the university as a whole.

Most of the students in our sample majored in an engineering degree: mechanical (44%), electrical (9%), aerospace (9%), industrial operations (7%), computer science (6%), biomedical (5%), chemical (3%), computer (3%), and other engineering fields (5%). Adding to the multidisciplinary nature more broadly outside of the College of Engineering, there were several students majoring in other disciplines such as Art and Design, Business, Informatics, Kinesiology, and Statistics (5%). The winter semesters (Winter 2013 and Winter 2014) were larger classes when compared to the fall semesters. The seasonal changes are driven by the underlying course scheduling requirements.

Milestones

We first compiled the data from the milestones identified by students. A total of 98 students were included in this analysis. We conducted chi-square analyses to find any statistical differences among the milestones reflected upon when our sample is divided by: sex, GPA, citizenship, minority identity, and underrepresented status. The chi-square test is effective in looking for differences in the entire range of the populations being compared. This statistic judges whether the whole range of responses is different for the populations; however, the chi-square test cannot pinpoint where specific differences and similarities occur. Based on the data, we speculated on the similarities and differences between groups.

Looking at the data for all students, milestones from the classroom, sponsored projects, extracurricular activities, and mentorship experiences had the highest percentages. Table 1 above shows the percentages of the different milestones when coded by our categories. Table 3 below presents p-values for the chi-square analyses for this project.

Table 3: Chi-Square Analysis by Comparison for Milestones	
Sex (Female and Male)	p=0.004**
GPA (<3.600 and >3.600)	p=0.011*
Citizenship (Non-residents; and U.S. Citizens & Permanent residents)	p=0.245
Minority Identity (Asian, Black, & Hispanic; and White)	p=0.152
Underrepresented Status (Black & Hispanic; and Asian & White)	p=0.002**

*denotes 95% Confidence Interval **denotes 99% Confidence Interval

Sex

The university data recorded students in binary fashion for sex demographics (males and females only). This has since changed in the last few years to allow for more choices. There were 360 milestones included in the analysis between sex (females: 102 milestones, males: 258 milestones). When looking at differences between males and females regarding their milestones, we determined that there was a highly significant difference between males and females (p = 0.004). This is within the 99% confidence interval.

After a comparison, we noticed that females did not indicate any milestones from experiences in internships and jobs. In contrast, about 4-5% of males reflected on each of those milestones. In addition, the data show that female students are reflecting on experiences from extracurricular activities and mentorship experiences at a higher percentage than males (27% to 16%, respectively). The fact that female students did not identify milestones from internships *or* jobs was somewhat surprising to us.

GPA

The GPA spectrum for the students had natural breaks at 2.800 and 3.600 out of a 4.000 scale. Three groups were initially created from these breaks: students with less than 2.800 (11 students), students between 2.800 and 3.600 (60 students), and students greater than 3.600 (21 students). For the chi-square analysis, we grouped those from the two lower GPA spectra into one larger group: less than 3.600 GPA. This group was then compared to the greater than 3.600 GPA group. There were 360 milestones (268 for students below 3.600, 91 for students above 3.600). This was done because the natural break is near the GPA that is equivalent to an A- for the College of Engineering at 3.700.

Through the chi-square analysis, there was a significant difference between the two samples (p = 0.011). This is within the 95% confidence interval. When analyzing the data, students with less than 2.800 GPA did not describe any milestones from internship experiences. The lower GPA can be used as a determination of academic performance, and obtaining an internship with the lower GPAs can be harder to achieve.

Citizenship

Citizenship in the initial data was sorted into three categories based on citizenship status: U.S. Citizens, Permanent Residents, and Non-Residents. For the analysis, we divided the students into two main grouping: non-residents compared with U.S citizens and permanent residents. There were 360 milestones (76 for non-resident students, 284 for U.S. citizens and permanent resident students).

A chi-square test was conducted and no significant difference (p=0.245) was found between the populations in regards to milestones. Despite no statistical significance, there were some notable observations including that there is a discrepancy in internships where only one milestone was associated with non-resident students, compared to 13 from U.S. citizens and permanent residents. There is also a large difference in team projects, 20% for non-residents and 30% for U.S. citizens and permanent residents. Interestingly, a higher percentage of milestones of non-resident students at 29% were listed for experiences in their extracurricular activities, compared to 17% for U.S. citizen and permanent students.

Minority Identity

Another chi-square analysis was completed comparing milestones between minority identities. In the demographic data, our students were categorized as: Asian, Black, Hispanic, Native American, White, or Other/Not Indicated. Minority students (our sample included Asian, Black, and Hispanic students) listed a total of 126 milestones. White students listed a total of 229 milestones.

In this comparison, the chi-square analysis revealed that there was no significant difference between white students and minority students (p=0.152). Though, minority students did not state jobs in their milestones. In addition, as seen in the spectrum of data for citizenship status, more milestones from minority students (25%) were listed as extracurricular activities when compared to white students (17%).

Underrepresented Status

The demographic data also included underrepresented (URM) status. We compared URM students (Black and Hispanic students in our sample) to non-URM students (Asian and White students in our sample). This comparison will allow us to examine the milestone data for historically underrepresented students. Non-URM students had a total of 327 milestones, and URM students had a total of 34 milestones.

A chi-square test showed that there was a highly significant difference in milestones between underrepresented students and non-underrepresented students (p=0.002) at the 99% confidence interval. The largest difference in milestones was for mentorship experiences which composed of 3% of milestones for underrepresented students and 28% of milestones for non-underrepresented students. Again, extracurricular activities were more prevalent in milestones from underrepresented students (35%) and non-underrepresented students (18%).

Professional Skills and Competencies Identified from Milestones

After examining the results from the milestones, we conducted a similar analysis on the professional skills they reflected upon and/or utilized during each experience. A total of 34 professional skills and competencies were coded for in the students' final reflection papers.

Chi-square tests were also performed for the analysis of the whole range of professional skills and competencies by means of sex, GPA, citizenship, minority identity, and underrepresented status. The chi-square analyses included all 34 professional skills and competencies to ensure an accurate statistical result. For these analyses, no statistical differences were reported from the chi-square tests for professional skills and competencies. (See Table 4 on next page). Some demographic information on the students was incomplete in the data; therefore, the total number of professional skills and competencies is not the same for each analysis.

Table 4: Chi-Square Analysis by Comparison for Skills

Sex (Female and Male)	p=0.152
GPA (<3.600 and >3.600)	p=0.272
Citizenship (Non-residents; and U.S. Citizens & Permanent residents)	p=0.851
Minority Identity (Asian, Black, & Hispanic; and White)	p=0.443
Underrepresented Status (Black & Hispanic; and Asian & White)	p=0.189

*denotes 95% Confidence Interval **denotes 99% Confidence Interval

When comparing differences between sex, females reflected on 284 skills and males reflected on 687 skills. For this analysis, the chi-square indicated that no statistical difference was found (p=0.152).

GPA was again analyzed from the natural break that occurred at 3.600, slightly lower than an A-average (3.700). Students below a 3.600 GPA reflected on a total of 735 skills, and students above a 3.600 GPA reflected on a total of 236 skills. We conducted a chi-square analysis, and no statistical difference was found (p=0.272).

For citizenship status, the same groupings of non-residents compared to U.S. citizens and permanent residents were analyzed. Non-resident students reflected on a total of 192 professional skills, and the U.S. citizen/permanent resident students reflected on a total of 779 professional skills. The chi-square analysis showed that there was no significant difference (p=0.851).

We also compared minority students (Asian, Black, and Hispanic) with White students. Minority students had a total of 317 skills and white students had a total of 626 skills that were reflected upon. The chi-square test reported that there was no statistical difference between professional skills and competencies between minority and white students (p=0.443).

Finally, underrepresented status was compared between historically underrepresented students (Black and Hispanic) and non-underrepresented students (Asian and White). Underrepresented students reflected on a total of 90 professional skills and non-underrepresented students reflected on a total of 881 professional skills. A chi-square analysis was conducted between the two populations and no statistical difference was present (p=0.189).

Analysis of Most Prevalent Skills

Due to the large number of skills that were coded, we wanted to analyze which skills were most prevalent in each population and determine if any differences were present. We believe that looking at these top skills provides a better picture of the most important skills reflected upon by students. The ratios of skills were compared among the populations to see if they deviated in a measurable proportion. In addition, we looked at cumulative percentages for all of the skills to understand how much of a proportion the top skills are present in the spectrum.

The analysis of the data shows that there were not any descriptive differences between the top 50% of skills when comparing: sex, citizenship, minority identity, and URM status. The top 50% of skills for these groups were composed of: communication skills, planning/organizational skills, group dynamics, and confidence. All groups shared these skills as the highest skills, but how many skills above the 50% mark differed somewhat.

We noticed some differences in the top 50% of skills between the 3 groups of GPA. We examined the groups created by the natural breaks in the GPA spectrum at 2.800 and 3.600. While there are some expected commonalities, all groups list communication skills, planning/organization skills, leadership skills, confidence, and group dynamics amongst the top, the differences here may yield the more illuminating conclusions. The low GPA group (<2.800) includes referenced skills in a more “basic” category: Time Management and Self-awareness of achievement. The high GPA group (>3.600) includes more “refined” skills: Teaching/Mentoring and Technical Skills. There is also much less variation of the top response from the high GPA group. All groups averaged about 11 categories per students overall, but the High GPA group showed little variation in their choice of the top 5.

The table below lists the skills that are most frequent that make up 50% of the total amount of all skills, grouped by GPA. The asterisks indicate categories that have at least 50% higher incidence in the particular GPA range (<2.800, 2.800-3.600, and >3.600) than would be expected in proportion to the students in the range. While this is not a statistically significant result; however, we note it because of the grouping of the skills (basic: Time Management/Self-awareness versus refined: Teaching/Mentoring and Technical Skills) seemed to speak to a different experience between the low and high GPA students.

Table 5: Top 50% of Skills Grouped by GPA		
GPA <2.800	**GPA 2.800 – 3.600**	**GPA >3.600**
Time Management*	Conflict Management	
Self-awareness of achievement*	Initiative/self motivation	**Technical abilities/knowledge***
Leadership skills	Teaching/mentoring skills	Teaching/mentoring skills
Planning/Organization skills	Leadership skills	Group dynamics navigation
Initiative/self motivation*	Confidence	Confidence
Group dynamics navigation	Planning/Organizational skills	Communication skills
Confidence*	Group dynamics navigation	**Leadership skills***
Communication skills	Communication skills	**Planning/Organization skills***

Table 5: The top 50% of skills are shown here. Each skill working down each column is reflected upon at a higher percentage than the skill above it. Asterisks/skills in bold indicate a 50% higher incidence in the particular GPA range. Cells highlighted in gray are skills shared among the three GPA groups.

Limitations

We analyzed the data in the aggregate form and did not analyze each student individually. This gives us a general survey of milestones and skills for a population sample. Given that students only reflected on five milestones each, and that those milestones only make up a small part of the bigger picture for past experiences, it is not possible to analyze students individually with any accuracy to determine the milestones they reflected upon or determine how many skills they described. We realize that this is a strength in looking at the data in terms of whole populations, but not when looking individually. Also, as this was an assignment for a course, there is the possibility that students could have written their version of what they thought would achieve the highest grade or what the instructor wanted to hear without actively reflecting on their experiences in the past.

Discussion

The data offer a glimpse into what milestones students acknowledge as being important in their development as well as the type of skills utilized in those milestones. The comparisons between sex, GPA, citizenship, minority identity, and underrepresented status provide a better picture about the spread of milestones and skills among certain population groups. Although there are statistical differences in three comparisons of milestones, looking at each milestone and skill category independently from the statistical analysis offers some interesting observations and questions.

It is notable the females did not reference work or internships as among their most significant milestones they reflected upon. In our experience with these courses, in class discussions, and in students' choices of mentoring styles and objectives, females tend to take part in extracurricular and project experiences in a different manner. Females relate their experiences based on less hierarchical organizations when internships and jobs for engineers are most often within a corporate or industrial setting.

We also noticed the differences in how males and females engage with one another in their organizations. There are differences in their approach in how they both articulate and exhibit their approach to engaging with others. Through our observations of these students, females place a different relative value on the experience of working with others.

Students with low grade point averages have less opportunity to pursue internships. Often, factors of GPA are commonly used as a "cut off" for many different jobs or graduate programs selections. Given the competitive nature of some internship opportunities, it may be difficult for students in the lower GPA spectrum to obtain internships. This appears to be true for this study since students below a 2.800 GPA did not reflect upon internship experiences.

However, instructor observations from class discussions are that the GPA had little correlation to a student's ability to understand and reflect on their project experience in a sophisticated manner. They were just as active in discussions and reflective exercises as students with a GPA greater than 3.600. Students in this seminar have successfully completed a major, open-ended engineering design project, and within this group we do not observe any obvious correlation between high GPA and sophisticated or well-developed professional skills.

We also find it quite surprising that no URM students referenced creativity and critical thinking as among skills. We do not have an explanation to explain this result. Creativity and critical thinking are higher-order skills that are important in the education process. Is it that URM students' perception of their engineering experience does not include this concept? Are they so focused on other things that these critical but more ephemeral attributes do not get named? We intend to probe this area further.

Although three milestone comparisons (sex, GPA, and URM status) are statistically different, there is no significance among the skills for any populations we analyzed. It seems as though, when analyzed in aggregate populations, students are utilizing the same types of professional skills but may be attributing those skills used to different milestones. This is another analysis that could be done in the future to pinpoint the skills that are attributed to certain types of milestones. In addition, there are interesting results when looking at the three GPA groups and the differences present in the top 50% of skills upon which students reflected.

When looking at the data for white students, we find an interesting observation and a topic that is worth examining in the program and collegiate environments as to how we counter students reflecting to give us the answers that they expect educators are seeking. This research is based on a final reflection paper needed to get obtain credit for this course and an academic minor. It is possible that some students know what the instructors are looking for and regurgitate the information back for a passing grade.

White students, from our data sample, seem to be writing about the "go-to" answers such as communication skills, planning and organization skills, navigating group dynamics, etc. more often than any other populations. We do not know if this is regurgitation of information, or if there is another explanation for their skills. How do we disrupt the narrative that there is a "right" answer in engineering education to more appropriately reflect engineering as a field that does not produce "correct" answers? How do we frame professional development skill acquisition outside of the regurgitation paradigm that exists within particular institutional environments?

Conclusion

This research offers a glimpse into which leadership and mentorship experiences students perceive as most important to their development as people and as engineering professionals. The course offers students an opportunity to break out of the technical pedagogy of engineering education and consider their experiences in a new light. The course is designed to challenge other learning paradigms through the reflective process. Reflection exercises from this course have a goal to more fully develop students as professional and well-rounded individuals.

Reflection is a vital component of student development in the college years. It provides faculty a tool to gauge where student are in the student development spectrum. In addition, the studied assignment contributes to student self-authorship, in the development of cognitive, interpersonal, and intrapersonal realms. This exercise contributes to intellectual development and the creation of the internal voice and self-advocacy, things needed as students move on to their professional careers.[25] Student development has the capacity to positively influence design skills, engineering knowledge, and professional development.

This final, reflective assignment can be utilized on its own as an easily implemented and effective way to incorporate integrative and reflective learning into an engineering design course. This is ideal given limited time available in the engineering curriculum for non-core skills/knowledge. The end of senior capstone design would be an ideal time to utilize this assignment as many students have experienced a significant synthesis of their engineering education and their general outlook turns to a more reflective mood as they complete their university experience. Students nearing the end of their undergraduate careers are more likely to have the intellectual and developmental maturity to reflect more thoughtfully on their experiences and benefit from reflection exercises and assignments. This specific assignment helps students make the connections to understand "what they have accomplished," "where they are," and "why it matters" in terms of their professional development. It has the opportunity to allow students to understand their professional trajectories and their leadership development philosophies just as they begin their professional careers.

There are differences in students' experiences when compared by sex, GPA, and URM status. A question that arises is: what is the optimal teaching pedagogy for the differences seen in these populations? Females did not include professional internship or jobs as part of their milestones. Does the fact that they note the most influential aspects of their experience outside the professional realm put them at a disadvantage in career development in today's workplace? Does it indicate a less developed skill or merely a different focus? Have they missed out on some aspect of professional development? Does there need to be a different approach to engineering pedagogy to ensure that professional and leadership skills are developed as much as possible? With regards to sex differences, we intend to reevaluate milestones in regards to how they select "other-centric" experiences. This will involve qualitative interviews with females in the sample to confirm or reject the conclusions we have drawn based on their milestones.

The leadership and mentorship course is offered to students who have completed significant design experiences and become leaders and mentors of design teams; it is usually taken in a student's last year. Although some differences exist in milestones and a spectrum of professional skills and competencies, there is a general trend in development reflected in the milestone chosen by students. The highest performing students tended to indicate a more sophisticated set of skills within their milestones. This may indicate that lower performing students do not benefit from the same experiences as higher-performing students, and therefore, are unable to practice higher-order skills in the same ways as students with high GPAs. To assist in the professional development process, it would be beneficial to introduce a similar reflective assignment earlier in a student's career and utilize the results to provide individually targeted support or opportunity for experiences. Completing this assignment earlier in the academic career will likely offer students an opportunity to more fully develop active reflection skills.

This work is the first of many possible analyses that could be conducted in this ongoing work. We are currently designing future projects to consider: (1) any differences in positive and negative experiences among the populations; (2) the distribution of skills within milestones, and (3) the importance of team versus individually based skills. In addition, research designed as a longitudinal study can be conducted by qualitative interviews or surveys given to the students from these course several years after graduation to see if the course and/or the active reflection has influenced their lives and/or professional careers in some capacity.

Bibliography

1. Kolb, D. A. *Experiential Learning: Experience as the Source of Learning and Development*. (Prentice Hall: Englewood Cliffs, NJ, 1984).
2. Kavenagh, L. & O'Moore, L. Reflecting on reflecting – 10 years, engineering, and UQ. *Proceedings of the 2008 AaeE Conference*, 1-6 (2008).
3. Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., Wenderoth, M. Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America*. 8410-8415 (2013).
4. Dewey, J. *Experience and Education*. (Macmillan: New York, NY, 1938).
5. Hey, J., Van Pelt, A., Agogino, A., & Beckman, S. Self-reflection: Lessons learned in a new product development class. *Transactions of the ASME* **129**, 668-676, (2007).
6. Woods, D. R., Felder, R. M., Rugarcia, A., & Stice, J. E. The future of engineering education III: Developing critical skills. *Chemical Engineering Education*, **34** (2), 108-117, (2000).
7. Woods, D. R., Hrymak, A. N., Marshall, R. R., Wood, P. E., Crowe, C. M., Hoffman, T. W., Wright, J. D., Taylor, P. A., Woodhouse, K. A., & Bouchard, C. G. K. Developing problem-solving skills: The McMaster Problem Solving Program. *Journal of Engineering Education* **86** (2), 75-91, (1997).
8. Woods, D. R. Problem solving – What doesn't seem to work. *Journal of College Science Teaching* **23** (1), 57-58, (1993).
9. Bandura, A. Self-efficacy mechanism in human agency. *American Psychologist* **23**, 122-147, (1982).
10. Bonwell, C. C. & Eison, J. A. Active learning: Creating excitement in the classroom. *ASHEERIC Higher Education Report No. 1*, (1991).
11. Davis, K. & Cline, C. Improving course comprehension through experiential learning. *2009 Construction Research Congress*, (2009).
12. Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. *Educating Engineers: Designing for the Future of the Field*. (The Carnegie Foundation for the Advancement of Teaching: Stanford, CA, 2008).
13. Socha, D., Razmov, V., & Davis, E. Teaching reflective skills in an engineering course. *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition*, 1-20, (2003).
14. Wong, F. K. Y., Kember, D., Chung, L. Y. F., & Yan, L. Assessing the level of student reflection from reflective journals. *Journal of Advanced Nursing* **22**, 48-57, (1995).
15. Schon, D. A. *The Reflective Practitioner: How Professionals Think in Action*. (Basic Books: New York, NY, 1983).
16. Bringle, R. G. & Hatcher, J. A. Reflection in service learning: Meaning making of experience. *Educational Horizons*, 179-185, (1999).
17. Doel, S. Fostering student reflection during engineering internships. *Asia-Pacific Journal of Cooperative Education* **10** (3), 163-177, (2009).
18. Williams, J. M. The engineering portfolio: Communication, reflection, and student learning outcomes assessment. *International Journal of Engineering Education* **18** (2), 199-207.
19. O'Moore, L. M. & Baldock, T. E. Peer Assessment Learning System (PALS): An innovative feedback technique for large engineering classes. *European Journal of Engineering Education* **32** (1), 43-55 (2007).
20. Mitchell, C., Jolly, L., & McLeod, A. On the way to reflexivity. *Proceedings of the 1998 AaeE Conference - Waves of Change*, 298-299 (1998).
21. Hinett, K. Improving learning through reflection – Part one. *The Higher Education Academy*, (2003).
22. Moon, J. Reflection in learning and professional development. *Theory and Practice*. (Kogan Page, London, 1999).
23. Meizrow, J. *Fostering Critical Reflection in Adulthood*. (Jossey Bass: San Francisco, CA, 1990).
24. Habermas, J. *Legitimation Crisis*. (Heinemann, London, 1976).
25. Evans, N. J., Forney, D. S., Guido, F. M., Patton, L. D., & Renn, K. A. *Student Development in College: Theory, Research, and Practice.* (Jossey-Bass Publications: San Francisco, CA, 2010).
26. Conger, A. J., Gilchrist, B., Holloway, J. P., Huang-Saad, A., Sick, V., & Zurbuchen, T. H. Experiential learning programs for the future of engineering education. *Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments, IEEE*, 1-14 (2010).