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WIP: Redesign of 1st Year Engineering Programs with Intentionality and Urgency

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Abstract:

This is a work-in-progress paper describing efforts to improve first year student experiences. The first year of any engineering program is critical for retention and identity formation. This 'year' provides approximately 300 days that can be used to impact the trajectory of each of the engineering students that enroll into our programs. As the body of knowledge in engineering has continually grown, the pressure to achieve meaningful progress within the first year has grown commensurately. At LeTourneau University, we've taken a hard look at the two-semester engineering sequence starting with an oft overlooked question – what are we actually trying to accomplish with and for these students? This paper describes the 6-step process that was used to investigate this issue (1. Team-building, 2. Goal Exploration, 3. Curricular Definition, 4. Interventions and Innovations, 5. Outcomes, and 6. Conclusions). Starting with assembling a team of invested faculty, we focused on determining the critical outcomes for the first-year using the collective wisdom of the group leavened with key findings from the relevant literature. With key outcomes at the forefront, it became apparent that defining all the various steps and activities and estimating the impact of each on the proposed outcomes across a sprawling enterprise that communally served six distinct program was a must. Key interventions and innovative concepts were considered and implemented, leading to specific changes in outcomes. This process was undertaken within an overarching assessment, measuring and metrics mindset – the faculty team and the students were surveyed at multiple key points in this process improvement exercise such that data-informed decision making could be implemented. This work-in-progress paper describes all of these key steps and the leadership and human factors involved and provides lessons learned and conclusions that can be used by other programs to maximize the impact of each of the approximately 300 days in the first year of engineering students.

Introduction:

The first year of any engineering program is critical for retention and identity formation. This 'year' provides approximately 300 days that can be used to impact the trajectory of each of the engineering students that enroll into our programs. As the body of knowledge in engineering has continually grown, the pressure to achieve meaningful progress within the first year has grown commensurately. At LeTourneau University, we've taken a hard look at the two-semester engineering sequence starting with an oft overlooked question – what are we actually trying to accomplish with and for these students? This paper provides a background that describes the characteristics of the engineering programs at LeTourneau University, plus the key courses and other elements influencing students, then describes the 6-step process that was used to investigate these issue (1. Team-building, 2. Goal Exploration, 3. Curricular Definition, 4. Interventions and Innovations, 5. Outcomes, and 6. Conclusions). As a Work-In-Progress paper, not all activities are finished – next steps are also discussed.

Background

Characteristics of LeTourneau University

LeTourneau University is a private faith-based polytechnic university. The school offers over 60 academic programs, including engineering and engineering technology, the aeronautical sciences, business, education, the liberal arts, and sciences. The School of Engineering and Engineering Technology (SEET) is the largest of these five divisions. Of the approximately 1300 undergraduate students on the campus, about 475 of them are in the SEET. The school offers B.S. degrees in Mechanical, Electrical and Computer, Civil and Environmental, Engineering Technology, and General Engineering. These programs all share a common core of first year through senior level coursework.

Existing First-Year Experience

The need for a robust first year program to support first time in college (FTIC) engineering students is well established. Much research has been done in this space over the past two decades. LeTourneau's awakening happened around 2009 when school leaders took a hard look at 6-year graduation rates and calculated a 5-year average of just 42%. An NSF Step grant entitled FIRE, First Year Initiatives for Retention Enhancement, was received beginning in 2010 with the goal of raising the 6-year graduation rates to 65% (Neimi et al., 2011). The plan was structured around the best retention practices at the time, with the following major initiatives:

1.) Development of a new 2-semester "Intro to Engineering" course sequence to replace the beginning "Engineering Graphics" course that was standard in all disciplines at the time. These courses would contain multidisciplinary projects to provide students with hands-on activities as well as answer the question "What do engineers do?"
2.) Development of the "Cornerstones" transition to college course utilizing engineering faculty to teach the course and mentor new students.
3.) Development of peer mentors to work with FTIC students by creating discipline specific first-year interest groups (FIG's) (Johnson et al., 2014).
4.) Development of an industrial mentor program to further expose FTIC students to understand the engineering profession.

While the FIRE project officially ended in 2017, most of the initiatives have survived and proven successful in increasing retention and graduation rates overall.

One of the major elements of the FIRE grant, the "Intro to Engineering Practice" courses are now well over a decade old since they were first developed. While the framework and overall course objectives have remained relatively intact, the process by which we arrive at those objectives has changed based upon the faculty involved in the course. Over the past fourteen years there have been at least sixteen faculty involved in teaching one of the two courses. With that many faculty involved there is bound to be some scope creep as many have their own ideas about what content would be best in the course. It became time to take a hard look at the objectives and curriculum of these courses to ensure they were still relevant, engaging, and accomplishing the overall objectives.

While the curricular elements of the first-year experience are important, it must be recognized that there are additional non-curricular and co-curricular elements of the first-year experience that have an influence as well. The ones in which the SEET has some control can be seen in figure 1. The next sections will expand on all three of these categories in more detail.

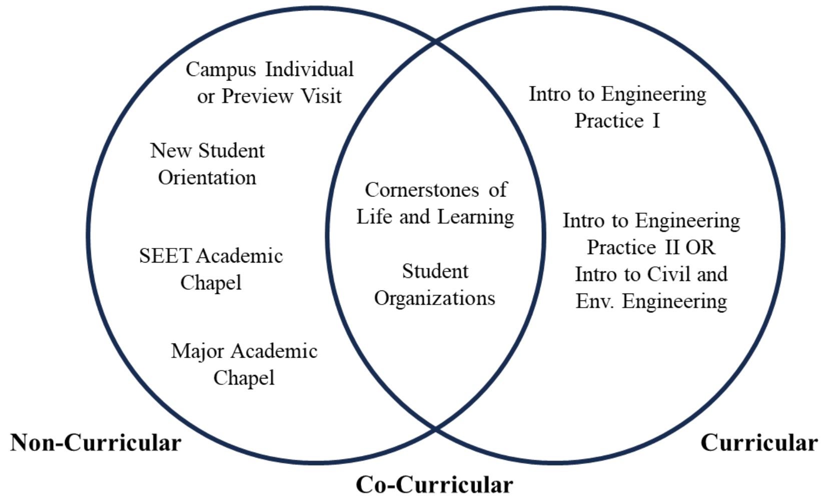

Figure 1: SEET elements of the first-year experience

Curricular
Due to the relatively small size of the SEET, the programs must share a common core of technical courses that are taught by a variety of faculty spanning across multiple departments. In the first year, these courses include:

- LETU1101 Cornerstones: transition to college course required by all FTIC students;
- ENGR1311 Manufacturing Processes Lab: 1 credit hour lab to teach machining and welding processes, required by all programs;
- ENGR1513 Introduction to Engineering Practice 1: basic introductory course, required by all programs;
- ENGR1523 Introduction to Engineering Practice 2: follow up course to go deeper into design method, required by all programs but Civil Engineering (they take CEGR1523 Introduction to Civil Engineering).

The focus of this paper is on ENGR1513 and ENGR1523, so more information will be provided on these courses.

ENGR1513 Introduction to Engineering Practice I catalog description reads as follows:

> "An introduction to engineering as a career, including problem solving, engineering disciplines, design, teamwork, and communication. An introduction to engineering graphics is included, with an emphasis on solids modeling."

And, the overall course objectives are as follows:

> "This course provides an introduction to the engineering profession, including the use of graphical modeling. The SolidWorks program will be used for the introduction to graphics. The focus of the course is to answer the question, "What do engineers really do?"

1.) The student will understand the basics of the engineering profession, including problem solving, design, teamwork, creativity, and ethics.

2.) The student will demonstrate the ability to communicate graphical information concerning three-dimensional objects.
3.) The student will produce, on the sketch pad and on the computer, assigned drawings of various objects."

Finally, the overall topics covered include the following:

1.) Engineering disciplines and functions
2.) Sketching and Orthographic Projection (Auxiliaries, Sections, Dimensions, Specifications)
3.) Spatial Visualization
4.) Solids Modeling
5.) Design methods
6.) Teamwork
7.) Communication
8.) Estimation
9.) Problem solving methods and tools
10.) Creativity and ideation methods
11.) Product design and prototyping
12.) Ethics

The course is structured with a 1-hour lecture that meets twice per week and a 1.5-hour lab that alternates every week between a build project and solid modeling. The nature of this structure has been a long-time criticism of the course by students who say it is essentially three different courses each with its own faculty and separate requirements.

The course includes a detailed build project with three main objectives: common skillset, sense of accomplishment at the completion of first semester, and provide tools and resources that the students could utilize for future projects and classes. The first year build project was incorporated into the LeTourneau curriculum beginning in Fall of 2010. For multiple years, the project was construction of an in-house developed 3D printer that each student constructed individually and kept at the end of the semester. 3D printing technology lost the novelty when more students were bringing personal 3D printers to campus and, for the project budget, commercially produced products were superior. The second iteration of the build project saw the era of the "useless" machine and two versions of pen plotters. This project taught the same skillsets, but did not keep the interest or excitement of the students as seen with the 3D printer era. Determining a third iteration of the build project was a task as part of the current research and is described later in this paper.

ENGR1523 Introduction to Engineering Practice II attempts to pick up where the first course ends. Its objectives are as follows:

1.) Participate as a member of a design team on a project; become familiar with the elements of engineering design and development including:
    a. problem definition and design synthesis;
    b. decision-making and team dynamics;
    c. goal setting, milestones, project planning, timeliness, and completion of tasks according to specifications.
2.) Develop a basic proficiency with the LabVIEW and Arduino programming languages.
3.) Develop a basic proficiency in project documentation via written memos and reports, and via oral in-class presentations.

4.) Become familiar with the engineering profession and professionalism, including engineering ethics, safety, quality, and social responsibility.

With the topics being the following:

1.) Three-Phase Design Process
2.) Writing as an Engineer
3.) Project Teamwork
4.) Quality Engineering
5.) Troubleshooting
6.) Entrepreneurial Mindset
7.) The Global Engineer
8.) Engineering Ethics
9.) Engineering Failures
10.) Brainstorming

While the first course is prescriptive in nature, the second is much more open-ended and team oriented in solving problems.

Non-Curricular Elements

The "first year" experience may not actually begin when the student arrives on campus for a new semester. There are some elements that precede this event and may have an impact on overall sense of belonging and preparedness prior to the beginning of the semester. Other non-curricular activities are specifically designed to facilitate connection and enhance the student's overall experience.

Non-curricular activities that precede a student's arrival on campus may include an individual campus visit or preview event. If a student opts for an individual tour, they are often met by the Chair or another faculty within their chosen discipline and provided a 1.5-hour tour of the classrooms and labs. These tours are designed to highlight the hands-on elements of an engineering education and often build in activities for the prospective student to get a sense of what it is like to be a student. Engineering preview events happen once per semester on a Saturday where prospective students spend an entire afternoon attending sample engineering classes, touring labs and enjoying engineering activities. These visits are designed to provide prospective students with an authentic experience and to help them identify with being a student. In addition to campus visits, accepted students into the programs are often emailed, called and communicated with by the chairs of each program thus further establishing a connection to someone on campus. In the summer preceding the fall semester, the University hosts day-long registration events on campus. This includes a sit-down meeting with engineering faculty to enroll in courses for the semester and answer academic related questions for the families.

Once a student arrives on campus there is a four-day new student orientation (NSO) program that is mostly facilitated by the Student Life department but does have some program level activities to foster connection within each school. This includes a SEET welcome event that introduces students to the school and places them together in their "Cornerstone" groups where they will meet their faculty instructor and are tasked with a team-building activity. The event ends with a meal together.

Additional non-curricular elements include "academic chapels" which are assemblies attended either by the entire SEET or broken up into departments or majors. These events often vary by department but are an opportunity to hear from chairs or other leaders in the departments, alums, or current students. They often allow departments to instill culture and champion the respective majors.

Co-Curricular Elements

The first-year experience has some elements that do not fit nicely into curricular or non-curricular. These include the transition to college course entitled Cornerstones, as well as student involvement in professional organizations.

Cornerstones is the first-year transition to college course required of all FTIC students. While the University has had this course for decades, it experienced significant development within the SEET during the NSF-Step grant from 2010-2017. During this time, the course transitioned from one which was owned and taught by faculty outside of the SEET to one that is now mostly owned and taught by faculty within SEET. Students are grouped by discipline into relatively small sections of 10-15 students. There is a faculty mentor assigned as well as one to two peer mentors (upper class engineering students who successfully navigated the first year). The course is designed to help the students develop in areas such as academic, social, spiritual, and professional development. It typically includes social activities facilitated by the peer mentors that might include dinner at the faculty mentors home, game nights, study sessions, field trips, or other unique experiences.

Another opportunity to foster connection in the first year is through student organizations. Both professional organizations associated with the students chosen discipline such as: ASME, IEEE, ASCE, SWE, SAE, AWS etc, or other types: Habitat for Humanity, Robotics Club, Theatre etc. The student life department hosts an annual showcase for all new students near the beginning of the semester. First year students within the SEET are encouraged to engage with the professional groups by advertising events in the Intro to Engineering Practice and/or Cornerstone classes.

With the above information as background, we started this project by looking at retention outcomes for students. Retention data is presented as averages across three-year incoming cohorts, with Early Attrition being defined as occurring within the first three semesters, and Late Attrition as any student leaving after the first three semesters and not persisting until degree completion. Finally, attrition here is measured as from the University, rather than from specific majors. A significant majority of all attrition observed was from the University. Attrition of approximately 1/3 of engineering students is significantly better than the national average of approximately 50%, but the SEET is considering adopting a significantly more aggressive retention goal.

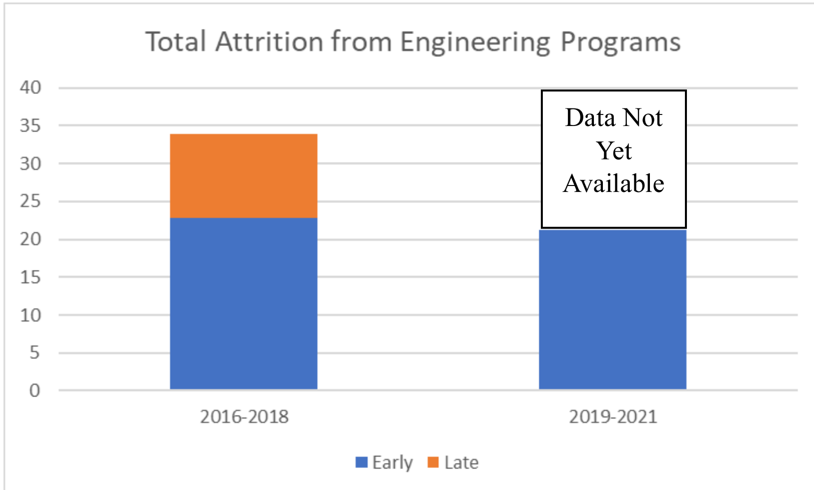

Figure 2: Retention data

Assembling a Team

As a first step in this process, it was necessary to identify the appropriate individuals to be at the table. All faculty who are involved with our two course first year engineering sequence (approximately ¼ of the faculty contingent within SEET) were invited/asked to participate. This accomplished broad representation from all of the Departments and faculty stakeholders. A task force was assembled with the following charge:

The first year in engineering at LeTourneau is a critical time for growth and assimilation. The purpose of this task force is to examine the first-year activities that SEET is responsible for delivering and ensure that they have been optimized to achieve goals for this group of students. In particular, this Task Force should:

1. Develop a comprehensive list of curricular, co-curricular and extra-curricular activities that SEET is responsible for delivering and that impact 1st Year students
2. Determine a specific set of measurable goals/outcomes for 1st year students.
3. Develop a week-by-week map of the activities noted in Item (1) above, and provide a matrix that associates these with the outcomes noted in Item (2) above.
4. Determine one or more sustainable, 'uncommon' student projects that can be delivered in a resource effective way across a multi-year time period and that help meet the goals and objectives identified in Item (2) above.
5. Provide recommendations for a streamlined, integrated suite of activities to be delivered in the next several academic years that take the work in Items 1-4 above into account in order to provide an enhanced experience for 1st Year students.
6. Deliver a summary report that captures the important features of the work outlined in Items 1-5 above.

Goal Exploration

Initial activities of the team included determining what the appropriate goals for the first year in engineering should be. Along with reviewing the literature (e.g. Veenstra et al. 2009, Soulsby, 2002, Asghar et al. 2023, Hoehne 2019), the team conducted a survey where each member ranked the importance of proposed goals, resulting in the data map as shown in Table 1. The last column of the table shows whether each of these goals was considered to mostly impact ‘technical,’ ‘relational,’ or ‘meaning and purpose’ aspects of engineering, based on two papers published that indicate the importance of all three of these aspects for engineering formation (McGinnis and Lett, 2023, McGinnis 2023). This process resulted in three findings: (1) most team members rated goals that were focused more on ‘relational’ aspects higher than others, (2) some goals needed to be retained even if viewed as less important, because there were no other logical places within a four year curriculum to put them (e.g. CAD) and the four year sequence requires their placement here, and (3) there was reasonable agreement amongst the team resulting in the adoption of 14 goals.

Table 1: Team Members ranking of the Importance of Proposed Goals

Goal	Leader	Member 1	Member 2	Member 3	Member 4	Member 5	Member 6	Member 7	Average	Type
6. Increase technical writing skills	3	2	1	5	4	2	3	4	3.00	Technical
10. Basic CAD skills	1	4	3	2	4	3	4	3	2.78	Technical
3. Identify with major [*Not selected as goal]	2	3	4	3	3	2	3	5	3.00	Technical
7. Improve design process thinking	2	2	3	4	4	3	3	4	3.00	Technical
8. Hands-on competency	2	4	3	5	2	3	5	4	3.33	Technical
16. Develop a sense of belonging	5	4	5		5	4	3	4	4.38	Relational
12. Fun/enthusiasm/attitude/affinity	4	3	4	4	5	5	5	4	4.22	Relational
1. Develop a network of peers	5	4	4	4	5	4	3	4	4.22	Relational
15. Connect with campus resources [*Not selected as goal]	2	2	4	5	5	3	2	3	3.11	Relational
14. Faith development	4	3	3	5	4	3	3	5	3.78	Meaning
17. Develop a sense of value (what I am learning matters)	3	3	4		6	5	4	4	4.00	All
18. Develop a sense of accomplishment	2	3	4		4	4	5	4	3.50	All
19. Develop a sense of professionalism	2	4	5		4	3	2	5	3.38	All
2. Identify as an engineer	5	5	5	2	5	4	4	4	4.33	All
13. Take responsibility for own learning	4	4	6	5	5	4	4	5	4.56	All
5. Be retained	5	4	4	6	1	5	3	5	4.22	

Curricular Definition

The background section of this paper outlines all the various activities with impact on the engineering first year. Although the two primary classes are important, many other pursuits play a role, an important observation on its own. A planned next step for the team is to create a day-to-day map of all of the activities noted, including identifying the person responsible and the team’s assessment of the activity’s contribution to each of the identified goals. This should allow for more intentionality and granularity in deconstructing this suite of contributors to enhance the overall experience.

Interventions and Innovations

The initial interventions considered were the following five: (1) Use a data-driven approach by surveying students to determine strengths and areas for improvement, (2) Reworking of student project, (3) Incorporate more team-based activities in first semester, (4) Better align lectures, lab and homework in first semester, (5) Create memorable events. The status of each of these initiatives is described below.

Survey Instrument

All students were given a survey in the first week of the semester that was based on a five-point Likert scale and that covered the goals identified by the project team. The initial results are shown in Table 2 below, which represents an “N” of approximately 125 students and over 90% of the total sample. 87% of the respondents were male, 13% of the respondents were female.

Table 2: Student Initial Survey Data

Goal	Faculty Ranking of Importance	Type	Student Perception of Skills
6. Increase technical writing skills	3.00	Technical	3.29
10. Basic CAD skills	2.78	Technical	2.01
7. Improve design process thinking	3.00	Technical	2.66
8. Hands-on competency	3.33	Technical	3.63
16. Develop a sense of belonging	4.38	Relational	4.12
12. Fun/enthusiasm/attitude/affinity	4.22	Relational	4.32
1. Develop a network of peers	4.22	Relational	3.21
15. Connect with campus resources	3.11	Relational	4.28
14. Faith development	3.78	Faith	4.25
17. Develop a sense of value (what I am learning matters)	4.00	All	4.85
18. Develop a sense of accomplishment	3.50	All	4.33
19. Develop a sense of professionalism	3.38	All	4.33
2. Identify as an engineer	4.33	All	3.84
13. Take responsibility for own learning	4.56	All	4.68
5. Be retained	4.22		

The two highest ranking were not anticipated by the project team: developing a sense of value, and taking responsibility for their own learning. The team considered that naivete and inexperience may have contributed to these rankings. Other scores that were relatively high included accomplishment, belonging, fun and on-campus resources. Skills that were considered 'technical' were scored low initially by students.

Reworking of the Student Build Project

The third iteration of the build project has completed the first cycle, remote controlled (RC) vessels – see Figure 3. For the fall of 2024, the vessel was a 3D printed boat coupled with an Arduino RC remote. The climax of the project was timed competitions of the boats on the pond located on campus. With this third era, the vessel coupled with the remote can change and improve every year. The hope is to keep improving on the initial concept with tertiary goals of making the first year students of this year jealous of next year's build project.

Students enter LeTourneau with a spectrum of experiences and through the build project a common skillset can be taught to be utilized for future labs and projects. Some have grown up tinkering, disassembling electronics and rebuilding them; some have helped with projects around the house; a few are at LeTourneau on the G.I. Bill coming back to school after serving our country; most have grown up constructing with LEGO® bricks; however, the other side of the spectrum have never used power tools or soldering irons.

The skillsets taught through this project are twofold: soft skills and physical skills. Soft skills include: attention to detail, time management, following instructions and manuals, reading Safety Data Sheets, and even become proactive in asking for assistance. The physical skills include, but not limited to: introduction to soldering techniques, hardware identification, and new manufacturing techniques, such as jig usage, post-processing, and 3D printing.

At the conclusion of the semester, the hope is that each student has completed the project. In Fall 2024 completion rates range between 80%-90% of the class. After the semester, every component provided in the initial inventory becomes an asset for the students to utilize for future projects, classes, or personal enjoyment. At the moment of powering-up the project for the first time, students complete the objective of a sense of accomplishment. The student is now one-eighth complete with their engineering degree program with the first real project behind them.

Figure 3: First-Year Build Project: (a) Completed RC boat with Arduino remote, and (b) Initial boat kit provided in tacklebox for storage and transport

Incorporating More Team-Based Work

When the "Intro to Engineering" sequence was first developed in 2010 it was envisioned that both courses would incorporate team-based projects to facilitate a sense of belonging and connection. In the early era of the first-semester course this was executed well as build projects were team-based and not individual, plus there were multiple in-class activities during the lecture requiring student groups of 3-4 to collaborate and finish the activity together. Additional team-based activities were incorporated in the solid modeling portion as well. The build project was shifted to individual when the students began the 3D printer project while other team-based activities dissolved for various other reasons. While this was true for the first-semester course, the second-semester course was structured around team-based projects. One criticism from the students that resulted in the elimination of some of the team-based activities is the random assignment of groups can sometimes create conflict. The task force decided to solve this problem by making two simple changes. First, we changed the group size from 4 students to 3 students thus making it easier for these smaller size groups to meet together, and facilitate more collaboration. The second change was to build in more relational topics into the lecture rather than keeping it strictly technical topics. The first addition was a lecture on conflict resolution. The next steps will be to assess how the team-based portions of the course are doing and continue to develop more relational topics into the lectures as necessary.

Better Align Lectures, Labs and Homeworks

A common criticism of the first-semester "Intro to Engineering" course was a disconnect between what was taught in lecture versus what the students were assigned as homework. Some of this may have been by design, but other times it was the result of poor development of changes in topics over the years and a failure to properly assign work that syncs with the topics and provides value-added work for each student. Therefore, the student does not see their homework as just "busy work" but instead allows them to dig deeper into relevant topics that were discussed in class. The Fall 2024 saw a partial effort to better align the weekly homework assignments with the lecture topics. We reworked the lecture series to tie more closely to the physical and graphics labs' goals and activities. Homework assignments were re-arranged and often rewritten to better follow the lectures and labs while also providing students with a number of discipline specific challenges at an introductory level. Graded activities include in-class-activities associated with the lecture lesson each period, homework assignments including lecture related questions, lecture related discipline specific challenges, and independent exploration of people skills and leadership characteristics in the engineering profession. The graphics labs provide a fundamental communications framework for all engineering and technologies disciplines – we worked to link the physical labs with the graphics labs at several levels through the course to provide synergistic learning activities. The next steps for this work is to review course evaluations to see if this effort was fruitful and to continue realigning additional homework assignments to the lecture topics.

Provide More Memorable Events

The culmination of the build project in particular is being designed to provide a high energy unique experience for students. The final demonstration should be exciting and mix competition and achievement in memorable ways. In the Fall of 2024, the weather did not cooperate well – it was cold and overcast during the final demonstrations of the RC Boats on the outdoor pond. Some rework in this area is ongoing as this project continues.

Outcomes

Since this project is not finished, no final outcomes are presented at this time. As one of the culminating activities of the Fall 2024 semester, the students were given the initial survey again. The investigators hoped to see positive changes in outcomes – Figure 4 below shows percentage differences from the initial administration of the survey.

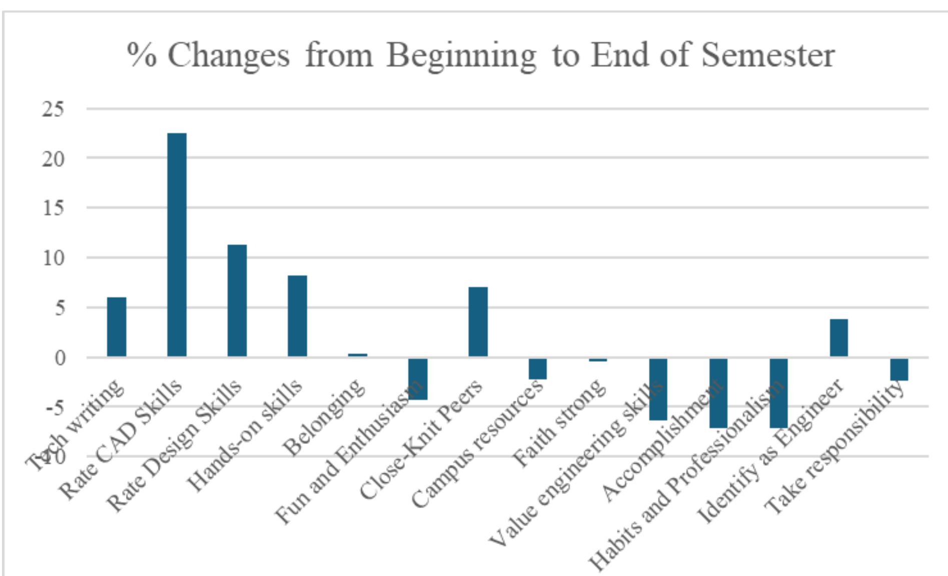

Figure 4: Changes in Survey Responses from Semester Beginning to Semester End

An initial observation is that students self-reported significant increases in 'technical' skills (e.g. CAD, tech writing, and hands-on skills). Relational and professionalism aspects showed mixed (i.e. belonging +0.3%, close-knit peers +7.0%, fun/enthusiasm -4.3%) or even declining (e.g. learning valuable skills -6.4%, habits and professionalism -7.2%, taking responsibility for learning -2.4%) results. Two possible explanations are: (1) the initial survey is given at a peak level of enthusiasm (Approximately Day 3 of the semester) while the final survey is given during final exam week, a relatively low point, and (2) as noted, initial responses may have captured naivete, while final responses may have captured more realism and a growing maturity. Further work will continue to interpret these results and determine their impact on future thrusts.

Conclusions

The following initial inferences are drawn:

1. The First Year isn't just courses but entails numerous activities spread across curricular, non-curricular, and co-curricular realms. Improvement projects need to incorporate an intentional look at all these aspects to maximize benefits.
2. It is important to mobilize a team to get buy-in across culture if the first year experience is a collaborative effort.
3. A framework of technical, relational and meaning and purpose aspects provides a useful lens and seems to aid in structuring interventions and making insights.
4. Students' initial enthusiasm and naivete, as contrasted with late semester fatigue and growing maturity may make interpreting before-and-after student data particularly challenging.

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