Bridges and Barriers: A Multi-year Study of Workload-related Learning Experiences from Diverse Student and Instructor Perspectives in First-year Engineering Education

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Introduction

This paper reports on the work of a multi-year research investigation conducted at the University of Toronto whose goal includes understanding workload-related learning barriers for first-year engineering students and suggesting approaches to mitigate those barriers.

Attrition of students in STEM (science, technology, engineering, and math) fields can be as high as 50%. A number of studies have attempted to elucidate the learning barriers that perpetuate such high loss rates for first-year college majors, citing both structural and cultural challenges in undergraduate STEM programs. The motivation for this work at our instiution emerged in response to anecdotal evidence (i.e. informal student conversations and feedback), suggesting that students are overwhelmed by their transition from high-school to first-year engineering. The intended outcome of this work is to establish a set of guidelines or principles that will inform the work of the first-year community at the instructional, advising, recruitment, and outreach levels. This study will ultimately situate across factors for success in post-secondary education (access, persistence, engagement, performance, graduation), with implications for both the student, instructor, and administrator, to better align preparation, expectations and support with what students anticipate and actually face in their first-year.

The principal research question leading this investigation asks: What experiences are reported as preparing for (bridging) or limiting (acting as barrier to) success in the first-year? As such, this study continues to explore information about workload parameters, including the perceived difficulty of course content, student experiences and perceptions in the first year and prior to the first year, and the construction of learning experiences in the first-year curriculum. This investigation analyses the responses of over 1000 first-year students collected over the study's first two years, using a combination of quantitative and qualitative approaches. Building on this work, our investigation delves deeper into understanding the complete first-year engineering student experience. We begin to construct a system context diagram and explore the difference that may exist across key elements of this system.

Background

Notions of how and why students find their way into STEM disciplines have been the focus of a number of research investigations. STEM pipeline models have exsited for many years, and emerged in response to economic and innovation concerns, as a means to effectively plan for sufficient numbers of professionals in relevant disciplines [1]. "Leaky pipeline" concerns emerged surrounding the disproportionate exit of marginalized youth from STEM fields resulting in underrepresentation. Early work in this area drew on supply-side economics and flow modelling approaches to support the generativity of workforce predictions. This model has been critiqued for over-simplifying the diversity of routes and experiences of STEM students and workers, and has been elaborated on by a number of researchers to better understand the influencers and trajectories of students interested, or not interested, in STEM [2]–[4]. Cannady et al. (2014) suggest a multipathway model to describe the route students take to engage in STEM, and consider a variety of factors influencing student choice, opportunity and privilege.

To better understand the factors contributing to student success in engineering in particular, Veenstra, Dey, & Herrin [5] offer a review of the literature to develop a comprehensive list of pre-college characteristics to inform a model for student retention in engineering. The characteristics in Table 1were found to be significant for student success in the first-year and for first-year retention.

Table 1 – Characteristics of high school students found to support first-year success

Characteristic	**Comments (brief)**
High school academic achievement	Indicator of academic preparedness; incoming grades/composite assessments
Quantitative skills	Analytical skills necessary for engineering student success
Study habits	Whether student is an independent learner; has experience maintaining regular study habits
Commitment to career and educational goals	Early identification of career goal(s)
Confidence in quantitative skills	Based on self-reported confidence in ability in science, mathematics and computers
Commitment to enrolled college	Associated with reasons for and satisfaction with chosen school
Financial needs	Initial access and retention issues often associated with unmet financial need
Family support	Parent income and educational level a factor for success
Social engagement	The degree of connectedness students experience with peers, teachers and faculty

It stands to reason then, that admissions criteria that seek out these elements (high achievement, quantitiave skills), retention supports that encourage these behaviours, skills and attitudes (i.e. study habits, confidence in quantitative skills, self-awareness and goal setting), can help bridge the gaps that students may experience (i.e. with respect to connection to their instiution, financial need, family support or social activity) when embarking on their post-secondary studies.

Additionally, pedagogical efforts have been made to engage students in active-learning experiences throughout their degree. It is acknowledged that there is a growing body of research that shows that students who do not find personal meaning or relevance in STEM will not pursue STEM beyond what is required in school [6], [7]. At the post-secondary level, the value of making those personally relevant connections persists, and as such, understanding the motivations, priorities and experiences of the first-year student can better inform interventions both pedagogically, culturally and structurally to promote success.

Methods

Data collection and participants

The principal method used in this study is the online survey and it is accompanied by focus-group work in context. We report on the results of three different surveys administered to students in their first year in 2016 and 2017 and supplemental discourse:

1. Engineering Welcome Survey (EWS)
2. Student Anxiety and Transition Survey (SATS)
3. Workload Measurement Survey (WMS)
4. First-Year Outcomes Discussion (FYOD)

Each of these surveys speaks to student expectation and experience at different points in the first-year. The Engineering Welcome Survey (EWS) was shared with all incoming first-year engineering students (n~1000) in mid-August to early-September of 2016, just a few weeks ahead of beginning their studies at the University. This survey focused on student expectations and motivations for, as well as conceptions of, engineering and was completed by 651 respondents. The Student Anxiety and Transition Survey (SATS) was completed in February and March of 2017 by first-year students (n=353) just beyond the mid-point of their first-year. The Workload Measurement Survey (WMS) was administered weekly, and was distributed by email to groups of 20 first-year students from each program throughout the first semesters in Years 1 (2016) and 2 (2017) of our study. These twenty students were selected at random from each of our 8 engineering programs each week; surveys were distributed at the end of the week for a twelve-week fall semester in order to encourage reflection and responses based on that particular week of study. In 2016, the survey received a response rate of 26.87% with a completion rate of 77.88%; in 2017, the response was 46.27% and presented a completion rate of 77.87%. This survey explored the perceived operational and conceptual difficulty of course content, the nature of that content, the perception of course assignments, deadlines and expectations, and the overall instructional experience. Data at the point of analysis was anonymized and used in aggregate to explore the elements under investigation. Questions asked in this survey include both quantitative (multiple choice, scale) and qualitative (open-ended) questions.

Survey respondents to the EWS and SATS were students entering (EWS) or in (SATS) their first-year of engineering; the WMS was distributed to a selection of students each week during the academic year. While we received information on workload and difficulty for additional courses through the WMS in each year, we chose to analyse student feedback on the same 5 courses as those reported in our previous study [8]. These present a combination of both technical and non-technical courses (Table 2).

Table 2 – First-year courses under analysis

Course Code	Course Name	Course Description
MAT 186	Calculus 1	Core course in Calculus for all first-year engineering students; includes discussion of limits and basic principles in foundational calculus.
MAT 188	Linear Algebra	Core course in Linear Algebra for all first-year students; includes an introduction to numeric computation.
APS 111/112	Engineering Strategies and Practice	Core course for engineering students; includes a focus on engineering design, teamwork, and communication. This course introduces and provides a framework for the design process, and uses a problem-based, active learning pedagogical approach.
CHE 112	Physical Chemistry	Core course for students in chemical, material, and civil engineering.
CIV 100	Mechanics	Core course in engineering mechanics, presenting and applying the theories of objects in motion as applied to frameworks of civil and mechanical engineering.

Rationale
We employed both quantitative and qualitative methods to better understand the dimensions of the challenge of workload for first-year students. This approach has supported data collection at scale, and has directed our tools of analysis as we learn more. We used quantitative methods to capture snapshot information from the large (~1200) class of first-year engineering students and qualitative methods to unpack the workload problem from multiple perspectives over time.

Ethics board-approved online surveys were sent to sample groups of students each week and at different points during the first year. The WMS formed the basis for the first phase of this study in Year 1 and identified points during the year where student workload mounted. Additionally, it allowed us to analyze stacked, student-reported workload in terms of time and the conceptual difficulty of individual courses. The analysis of qualitative data established a series of themes that categorize the types of concerns expressed by students throughout their experience.
As our data are not coming from the exact same students each week, and in large part due to an effort to prevent survey fatigue, our interpretations are based on the reasonable assumption that the responses again present pseudo-random sample groups of 20 first-year engineering students that are statistically similar samples. This has enabled us to collect regular data from groups of students with weekly frequency with, we believe, minimal impact on student experience.

There are a number of important considerations that inform our work. While, student workload can be interpreted in a number of ways, we consider it to be a multidimensional construct that can be modified based on a number of factors that impact the student and their environment. Workload can simply be considered the amount of work required of a student in a given period of time, but we draw on Bowyer's definition that expands on the typical definitions of workload to incorporate the time needed for contact and independent study, the quantity and level of difficulty of the work, the type and timing of assessments, the institutional factors such as teaching and resources, and student characteristics such as ability, motivation and effort [9].

One assumption that we make is that students are honest about their effort and that their self-reported data is a reliable representation of reality. We believe this is important to acknowledge, as the output of this work influences our, as well as that of our colleagues, understanding of workload and student experience in the first-year. Another consideration we hold is in the quantitative assessment of the data. For our larger datasets, we chose to use the median value as a measure of central tendency to better present the student population as it is ordinal. This permits us to account for potential outliers in each sample group on a weekly basis and better serves our interest presenting data on collective experience rather than the full details of individual student experience at this point.

Results

We report on the relevant findings from three student surveys and related adminstrative discussion, presented in order of the relevant volume of data under consideration:

1. Workload Measurement Survey (WMS)
2. Engineering Welcome Survey (EWS)
3. Student Anxiety and Transition Survey (SATS)
4. First-Year Outcomes Discussion (FYOD)

Workload Measurement Survey (WMS)

The majority of our data are drawn from the Workload Measurement Survey, which offers a compilation of data acquired over the span of two consecutive years. It includes data for conceptual difficulty and hours spent outside of class for five first-year courses. From the available data, we have opted to focus on the accumulated hours spent by students outside of class for all of the courses, the average number of hours spent out of class for each course individually, the median conceptual difficulty level reported by students for each course, and the dimensions of workload students have reported through their open-ended responses.

We continue to explore the same metrics from the WMS that we had explored in the previous year's data and compared the embedded elements year-over-year. We found that the number of hours spent out of class on school-related work (i.e. homework, assignments, studying) remained relatively similar during the same period. Of particular note is that the reported hours for all courses appear to have stabilized somewhat over the smester, with less of dramatic spike in hours during the mid-term period being evident. It is also notable that students are spending less time working on non-technical material out of class than they were in the previous year (Figure 1; Figure 2). However, students do report spending up to 28 hours a week outside of classes on schoolwork, which, when combined with in-class hours (on average, 27 hours a week) does restrict the amount of time available for personal activities and downtime. In 2016, we observed that week 5 (Oct 7) and week 8 (Oct 28) indicated times when student efforts were accentuated. In 2017, student efforts climb in the second week of class (Sept 16), and appear to stablize but increase over time through the semester when they spike again prior to final assessments (Nov 27). We do again see that tests and assignments appear to be scheduled at comaprable intervals across courses. And in both years, we see a dramatic increase in time spent out of class after the first week, suggesting that students are making adjusutments to efforts in response to their transition to university. It is important to note that the five courses under consideration do not present a full picture of course workload in the first-year, as students are taking additional courses. This indicates that students are spending more than the combined average (27 hours of average class time plus 28 hours of out of class time) of 55 hours a week on their studies at a minimum.

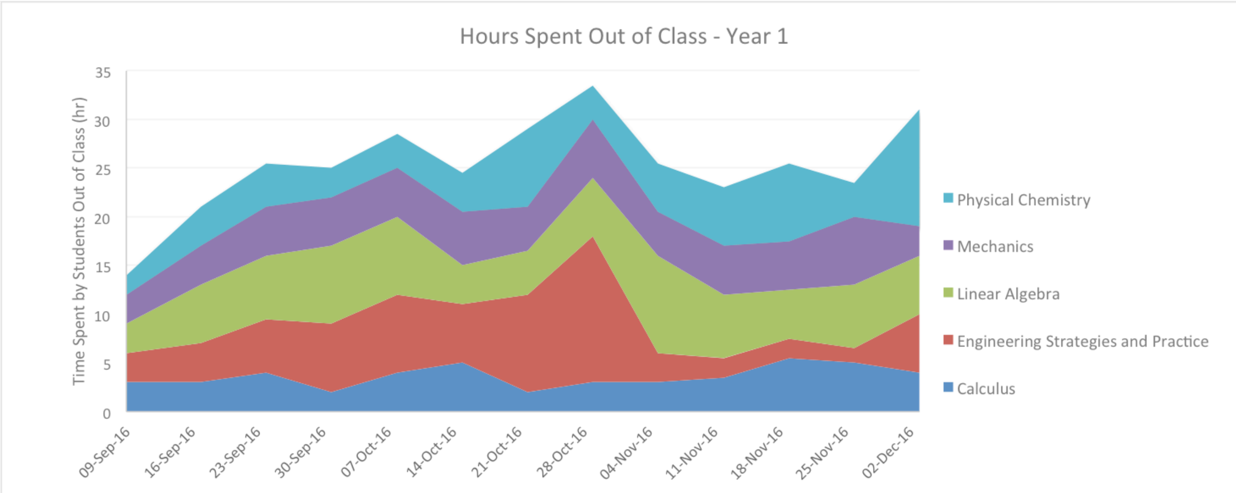

Figure 1 – Number of hours spent outside of class on first-year courses for Year 1 of the study

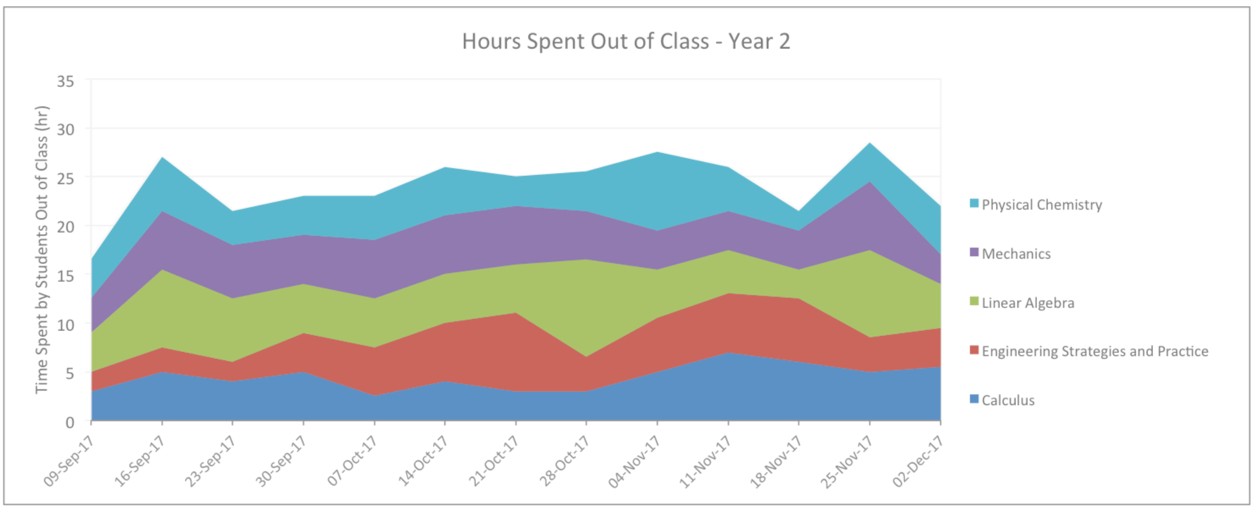

Figure 2 – Number of hours spent outside of class on first-year courses for Year 2 of the study

From the WMS, we also explored median perceived difficulty (Figure 3; Figure 4) and the average hours spent outside of scheduled class time for each course in Year 1 and 2 of our study (Figure 5; Figure 6). In Year 1, we saw a stronger association between difficulty and hours, and we were able to conclude that students on average spent more time on courses that they perceived to be more difficult. Students on average spent more time on Engineering Strategies and Practice (ESP), the first-year design and communication course, and Linear Algebra in Year 1. In Year 2, this trend continues, however, we do see a drop in the reported time spent on ESP, as well as a drop in the perceived difficulty of course content. Last year, we considered that high school curriculum, or student preparation, was informing these results, as the majority of students have limited prior exposure to the content of these two courses (Linear Algebra and ESP). However this year, we see that the Mechanics and Physical Chemistry courses ranked alongside Linear Algebra in terms of perceived conceptual difficulty. This may continue to suggest that students were not prepared to take on the demand of these courses and hence tried to compensate for their lack of preparation by spending more hours studying these courses. On average, it appears that students found all the first-year courses to be difficult as their perceived difficulty is always higher than 3, on the 5-point Likert scale rating.

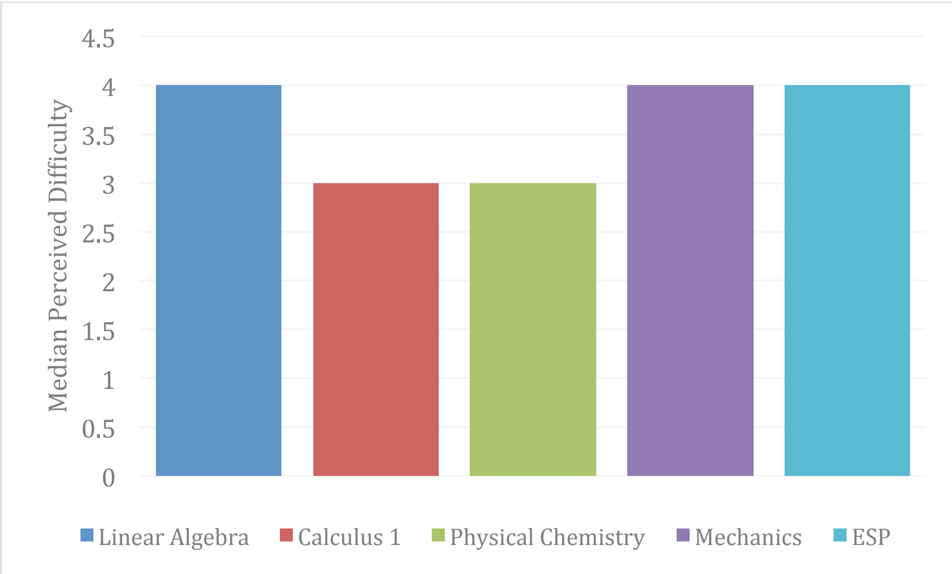

Figure 3 – Median perceived difficulty for each course for Year 1 of the study

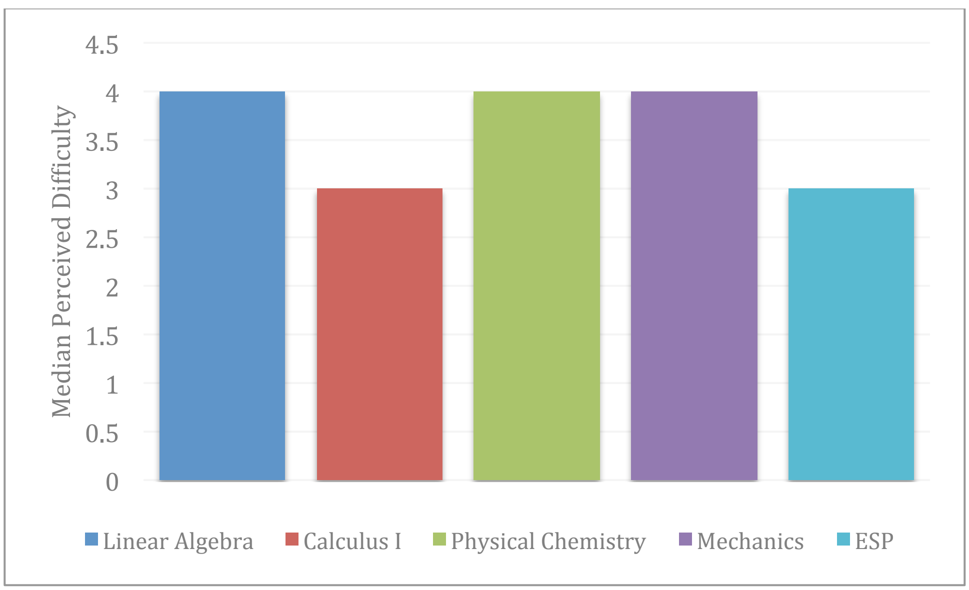

Figure 4 – Median perceived difficulty for each course for Year 2 of the study

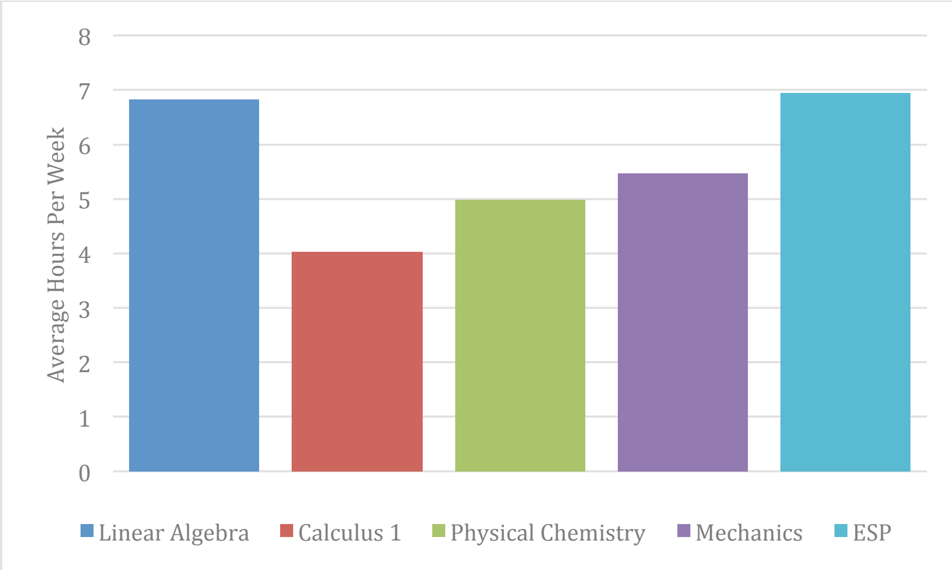

Figure 5 – Average hours spent outside of class time on each course for Year 1 of the study

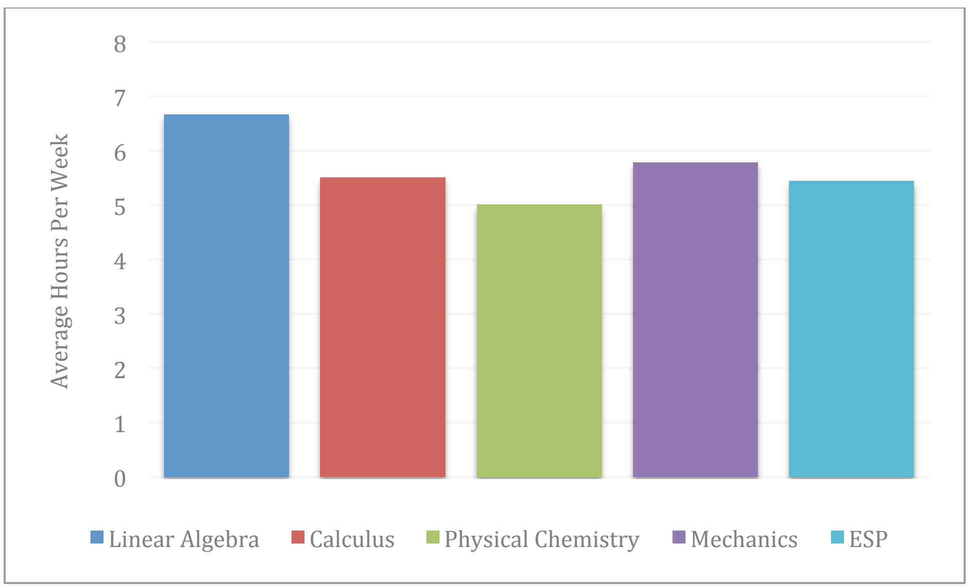

Figure 6 – Average hours spent outside of class time on each course for Year 2 of the study

To add context to the perceptions observed in the quantitative data, we also explored responses to a final over-arching open-ended question asked in the circulated WMS: *Do you have any other comments that will help us better understand first-year student workload?* We acknowledge that students offered substantial feedback and additional context for their survey responses and appreciate their candidness and openness in sharing their experiences.

Emergent groupings for these responses were identified and these data informed the creation of the following thematic codes or categories, which are the same as the previous year:

1. **Time**: References to student time available to study and for leisure; the scheduling of classes; the scheduling between assessments; differences in the amount of work or effort required week-to-week

2. **Volume**: References to volume or quantity of work; whether the work was manageable, too much, notions of keeping or catching up with course pace; differences experienced week to week and across courses.

3. **Course and Program Content**: References to the perceived difficulty of; sequencing of material and assessments; perceived value of non-technical courses; differences between courses.

4. **Transition**: References to an adjustment period or changes; feelings of preparedness; differences perceived when compared to their high school experience.

5. **Instruction**: References to the perceived quality of instruction; instructor organization and modes of content delivery, how 'well' the course is taught; differences in the instructional 'success' between courses.

6. **Communication**: References to institutional emails; perceptions of extraneous information; difficulty navigating multiple platforms and online tools.

7. **Expectations**: References to the clarity of expectations on the part of the instructor, course or program; differences between communicated expectations and lived experiences.

Year-over-year, we see the same lead themes presented in student writing. However, from the number of qualitative repsonses received, the ranking of these representative categories has shifted (Table 3). Ranking is determined by the number of times that the theme presented in student feedback as a unit of meaning. The most notable of these shifts is the movement of the "Transition" theme from a 4th ranked position to a 3rd ranked position: this represents that over twice as many students as the previous year mentioned transition issues in the workload comments (5 incidences in Year 1 to 12 in Year 2). Another shift is present in the content theme: we found that less than half as many students mentioned course and program content in their workload-related comments (24 incidences in Year 1 to 11 in Year 2).

We acknowledge that these thematic categories are interpretive but these changes do suggest that issues of transition and preparation for life in first-year engineering and at university appear to be figuring more prominently in students perceptions of their experience.

Table 3 – Themes identified in open-ended student responses for Years 1 and 2 of the study

Ranking	**Year 1 (n=149)**	**Year 2 (n=97)**
1	Time	Time
2	Volume	Volume
3	Course and Program Content	Transition
4	Transition	Course and Program Content
5	Instruction	Communication
6	Communication	Expectations
7	Expectations	Instruction

To inform our review of this data in the previous year, we looked at the scheduling of assignments in temporal relationship to these elements. This year, we appeal to the EWS, SATS, and FYOD to deepen our interpretations and analysis.

Engineering Welcome Survey (EWS)

673 first-year students responded to this online survey in August before beginning their first-year engineering program of study at our institution. Students were asked a variety of questions related to their personal motivations and expectations for the year and program ahead.

Important relevant findings we wish to report on from this survey include the following:

- The majority cite their top reason for choosing engineering as "engineering is related to my interests in mathematics and science" (80.71%), with the next three categories being "job security" (39.82%), "to positively influence my community/the world" (34.11%), and "because I wanted to enrol in a program that would challenge me academically"(31.79%).
- When asked to select the option that best describes agreement with the statement: "I've developed a clear academic plan for my university education", close to 70% of students indicated that that they strongly disagreed, disagreed, or neither agreed nor disagreed with the statement, suggesting that many students do not have a fully formed plan for their education entering the first-year.
- When asked if they agreed with the statement, "I can succeed in an engineering program", only 1% of incoming students disagreed or strongly disagreed; 87.25% agreed or strongly agreed that they were poised to succeed in their program. Similarly, when asked if they agreed with the statement "I can persevere in engineering during the upcoming academic year", over 90% of students strongly agreed or agreed with this statement.
- Students were asked if they felt that their previous educational experiences had prepared them for their first year at university. 23.95% said "Yes, completely", 51.30% said "Mostly", 22.55% said "Somewhat" and 2.20% said "No, not at all", suggesting a

considerable degree of self-confidence or assurance in student preparation before embarking in the first-year of their engineering program.

Student Anxiety and Transition Survey (SATS)
349 students responded to this online survey that was written and distributed by current engineering students electronically to first-year engineering students at 6 different instiutions across the country. This survey asks a series of demographic questions (i.e. institution, program of study, living arrangements) as well as questions that sought to inform student identity and experience.

Important relevant findings we wish to report on from this survey include that:

- Only 19.4 % of students reported living with parents; over 80% indicated that they lived independently, with our without housemates, either on- or off-campus
- 75.6% of students reported moving to attend their program of study; of these, 48.5% moved city, 26.1% moved province, 7.9% moved country and 17.4% moved continent
- 31 students (9%) reported being the first in their family to go to university
- Students were asked to rank how prepared they believe they felt coming into their program of study and how they felt now (in February) on a scale of 1 ('Not prepared') to 5 ('Very prepared'). Students indicate an average initial preparedness rating of 3.5 or 'Somewhat prepared'. The average change in this self-reported level was a decrease of .36, from 3.5 to just over 3.1, suggesting students now consider their initial assessments inaccurate.
- Students were asked: "Are you thinking of dropping out?". Of the 318 responses, 74.8% indicated that they are not considering dropping out. However, 25.2% are at least considering dropping out at this point in the year (22 indicated 'Yes' and 58 indicated 'Maybe').

First-Year Outcomes Discussion (FYOD)
To supplement our understanding of these elements, we contextualize the first year experience as being part of a planned program with specific outcomes in mind. Here, we report on the results of an informal focus-group discussion among first-year educators focused on identfying high-level outcomes of the first-year engineering experience at our instiution. These interpretations of the goals of the first-year curriculum on the part of the first-year educator, speaks to the demands and expectations that construct the students' learning environment. Faculty articulate their expectations for the curricular foundations of the first-year experience, which include the knowledge, skills and attitudes they consider essential to establishing better alignment with incoming student expectations in hand with instructor expectations.

As they exit first-year, faculty assert that students should be able to:

1. Understand the principles of professional behaviour.

    a. Identify and utilize standards of academic honesty/integrity.
    b. Indentify how the foundations of engineering ethics impact their experience.
2. Articulate unique, personally relevant examples of how the things they are learning apply to the real world.
3. Demonstrate interpersonal and relationship skills, such as tact, diplomacy, teamwork.
4. Demonstrate logical thought process to break up a complicated problem into simple, resolvable steps or segments.
    a. Utilize algorithmic/computational thinking/design processes.
5. Apply basic principles, relationships, and mathematical laws to solve problems.
6. Understand the principles of developing a model for a complex system, and recognize and evaluate the limitations of that model.
7. Extrapolate their knowledge to new situations and solve new problems, and recognize and evaluate the limitation of that process.
8. Develop credible arguments and communicate these as justifications for their choices.
9. Talk to anyone about a first-year course topic with appropriate terminology.
10. Take responsibility for their own education and emerge as life-long learners.
11. Think critically; be able to examine their own work and find its flaws, if any.
12. Generate more than one way to solve a problem, and be able to appreciate which solutions are more elegant than others.
13. Articulate the complementary roles of the various engineering disciplines.
14. Demonstrate an understanding of the curriculum overview for their program of study.

Working from each of these locations of student experience, we will discuss the bridges and barriers that may be drawn from these various perspectives.

Discussion

Bridges and Barriers

Overall, this paper aims to contribute to an understanding of the experience of the undergraduate engineering student in their first-year, how students interpret the demands and stresses of their program of study, and their interpretations of workload. The data from this investigation appears to suggest some consistency of student experience year-over-year. While the interpretations brought forth in the context of this initial exploration may not allow us to make any major recommendations at this time, they do highlight interesting notions of the spectrum of student experience to advance the work of the engineering educator to better support the incoming student.

We continue to see evidence of the workload factors described in the literature manifesting in this population. Traditional definitions of workload incorporate the time needed for contact and independent study, the quantity and level of difficulty of the work, the type and timing of assessments, the institutional factors such as teaching and resources, and student characteristics such as ability, motivation, and effort [9]. These characteristics map indirectly to the 7 emergent categories that seem to describe reported student workload experience in their first semester. Many of these constructs are delineated in traditional notions of workload, however as we discovered in our initial investigation, these notions collapse to be referred to in tandem, and can be conceived as related or co-acting concepts. We can continue to consider the major areas of concern in this way, where there is a relationship in student perception between Time and Difficulty, Volume and Difficulty, and Course Content and Difficulty, as indicated by the quantitative assessments of courses provided by students. This year, we discovered evidence of co-acting concepts in student qualitative responses and found that students noted Time, in descending order, together with Volume (9 times), Transition (4) and Course and Program Content (3). Transition issues were most closely linked with Instruction and Course and Program Content (both 4 instances). While these present only a small number of student insights into these linkages, more in-depth analysis may further elucidate how these come together to form student notions of workload.

Transition elements of workload have been a more prominent element in this year's research and indicate that efforts to engage with students *prior* to the first-year in meaningful ways can assist in the transition from high-school to the program of study. While this includes a host of non-academic factors associated with living away from home, unpacking the data that surrounds feelings of preparedness before, as compared to during, the first-year, indicate that there is a discrepancy between student self-assessment of their level preparation. This is also evident in student perception of their ability to persevere in their program of study, coupled with the reality that one-quarter of all students are considering dropping out and leaving their program mid-way through their first year.

Time continues to present as a dimension of workload that students report as concerning, and that may be acting as a barrier to success. In the qualitative responses for Year 2, students have begun to describe solutions for modifiying or optimizing their available time. Their constructive suggestions include minimizing long breaks between classes, the value of various working examples of successful student schedules who have been able to manage their time and thrive in their first year, and they also suggest lobbying the local transit system to commit to installing 'wi-fi' so that commuter students can use their transit time (in some cases, over 3 hours a day return in the city) to stay academically productive in transit.

In every case, the ambitions of the first-year curriculum as articulated through the FYOD (#'s 1-14 above), align with considerations for *The Engineer of 2020* [10], that asserts that the following would be key attributes of an engineer in the near future:

- Strong analytical skills (#4, 5, 6 and 7)
- Practical ingenuity (2)
- Creativity (12 and 13)
- Good communication skills (8 and 9)
- Master principles of business and management (3)
- Leadership (3)
- High ethical standards (1, a and b)
- Dynamism, agility, resilience, flexibility (11 and 12)
- Lifetime Learners (10, 11 and 14)

This suggests that the instructors participating in the FYOD have expectations well-aligned with the anticipations of research. These expectations seem to situate around two central themes, informed by each other:

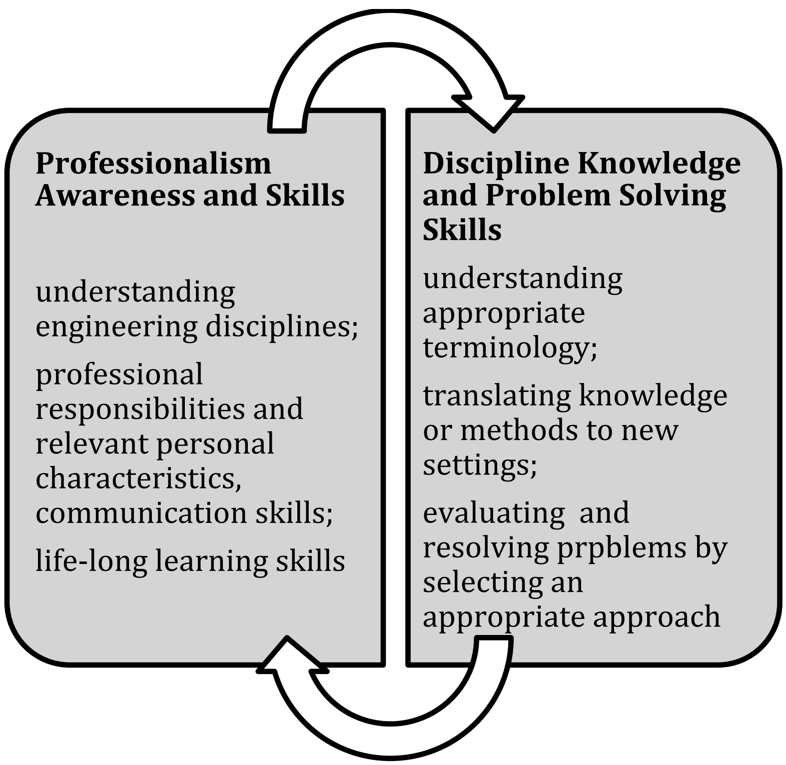

Figure 7 – Two inter-related central themes presented in the First-Year Outcomes Discussion

The attainment or demonstration of these skills present as a *bridge* to student success after the first-year, which help to situate these findings within a larger scope or system of experience. These elements in particular help guide advising and curricular experiences for first-year students.

System Context

We can begin to situate these findings within a model that considers workload as a part of an existing and evolving system of experience for the first-year engineering student, but that is informed by factors that exist beyond the workload dimensions we depict as themes. These dimensions are the product of a system of experience that students enter into and are a part of; a dynamic system of engagement in which the student exists. We can consider the experience of the engineering student described as those *prior to* coming into the program that they describe, their experience *during* the program itself, and the outcomes or goals *after* the first-year ends.

Student experiences prior to the first-year include those experiences of home, family, friends, school and out-of-school learning experiences, though in the system context diagram (SCD) below, we indicate these as "School experiences", " Outreach experiences" and "Other pre-FY experiences" (Figure 5). All experiences that occur prior to the first-year (FY) are indicated by a dotted arrow. For those interactions that occur during the FY, the relationship is indicated by a solid arrow. Depending on the nature of these experiences and resources, they may be considered either a *barrier* or *bridge* to success for the first-year student.

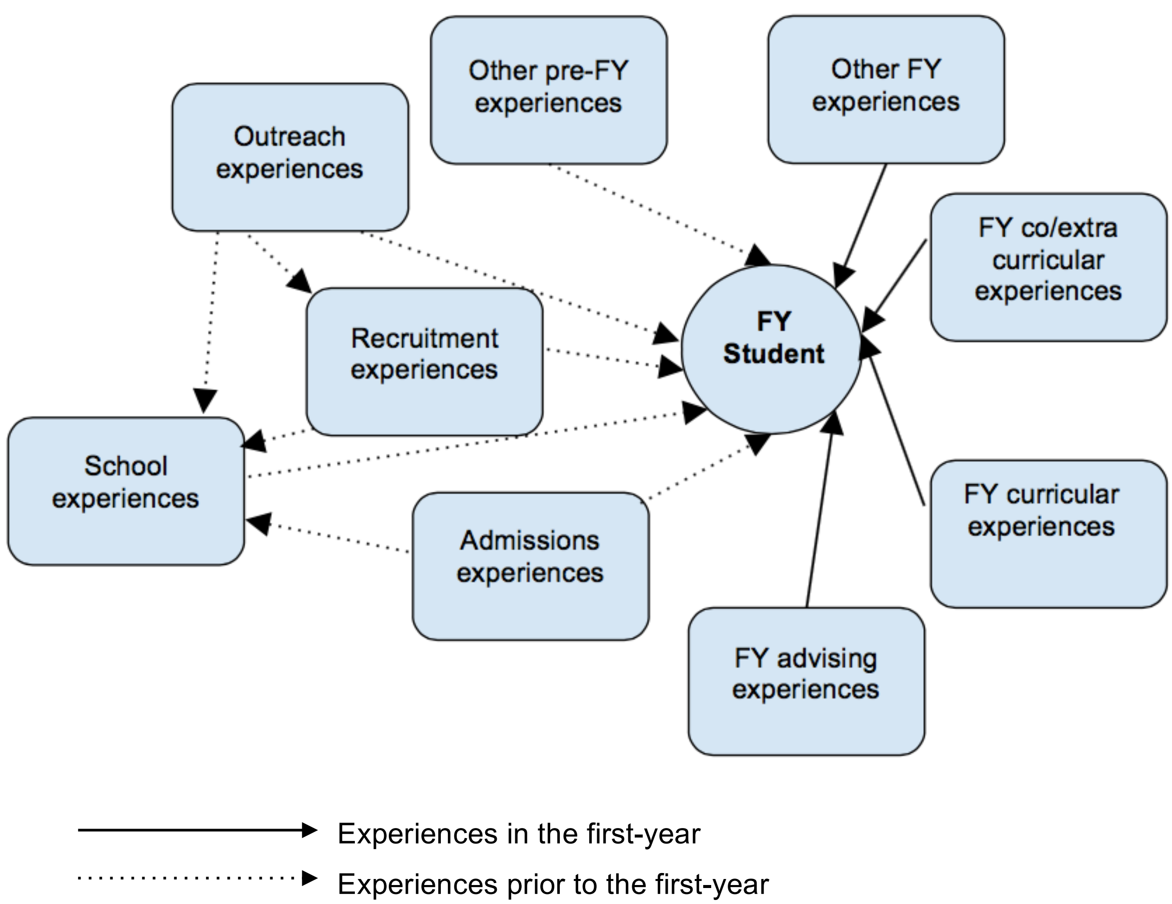

Figure 8 – System context diagram (SCD) for the first-year (FY)

Conclusion

We begin to construct a system context diagram (SCD) to identify the interaction or experience types at work across a student's spectrum of engagement in the first-year. We posit that the scope of experience of the student in the first-year is in a system comprised of interactions that rest largely within the influence of the University. As we begin to visualize and map the interactions of the first-year engineering student, we explore the perceptions and relationships that exist and the ideas that undergird these elements. We believe that each of the interactions experienced by the student in this system may be considered either a *barrier* or a *bridge* along a personally defined pathway of success, and determining how to best inform these interactions may be made possible through additional exploration of these experiences. Further research will seek to understand, across the elements in the SCD:

- What elements contribute to student perceptions of preparedness and perseverance prior to and during the first-year?
- How can perceptions of the articulated dimensions of workload be augmented for student challenge and success?
- How can educators leverage fundamental student interest in their program of study to promote student success?
- How can administrators in admissions, advising, recruitment and outreach areas, as educators, support student success in the first-year?
- What experiences inform student expectations of the first year?

These questions persist across student experience but a starting place may be the student's earliest interactions with the university and the discipline or program of study itself. Considering the characteristics of success identfied by Veenstra et al (5), we can effectively work 'backwards' to foster the elements of success for future students. If outreach or pre-university efforts begin as early as kindergarten, as they do within the institution under consideration, it is possible to offer students opportunities to better understand programs of study, to foster interest and align relevant conceptual knowledge and skill development with programmatic expectations. Similalry, working 'forwards' has incorporated an understanding of the critical needs of the graduating engineer and their professional repsonsibilities. The evidence points to the important role of educators in collaborating across instituional areas to construct learning experiences and interactions that align with the current realities of first-year. We suggest that experiences that cultivate self-awareness and foster student resiliency, encourage the clarity of consistent and available information, focus on the mastery of foundational math and science expertise, and present as a navigable system of supports, set students up for success as undergraduates. We will continue to look at these elements as a system of experiences at work, acknowledging how particular elements can be integrated into the first-year experience, and prior, to create a lasting effect.

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