Student Learning Strategies: helping or hindering their success?

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Abstract

This research paper examines student success in undergraduate engineering through the lens of students' priorities, practices and values. While most engineering schools implement retention-based student success models that monitor student expectations and levels of satisfaction, it remains a challenge to know what strategies students use or how successful those strategies are. Self-management, one of five student-centred dimensions deemed vital for student success, examines ways in which students approach, or avoid, their studies. Research suggests that a "can-do" attitude, self-discipline, good study habits, and active engagement in the learning process are essential for student success, and that the ways students approach or avoid their studies can predict whether or not a learner will be successful.

Engineering students enrolled in a small engineering school were invited to complete an online survey examining the types of strategies they use in order to be successful. A set of forced-choice questions was used to rank strategies related to class time, completing assigned work, note taking, studying, and overall work ethic. Responses were validated using a set of related Likert scale questions, and a set of open ended questions allowed students to identify strategies they believe contribute to, or impede their success. Correlational analysis and predictive classification were used to determine the key behaviour indicator(s) of student success, and the specific behavioural factors associated with different levels of academic success.

Findings indicate that the key behavioural indicator of student success is actually doing the assigned work. This is also the most important predictor of students who maintain an A-level grade point average (GPA). B-level students put less emphasis on a good work ethic, use less effective study habits and do not prioritize attending class. C-level students put low priority on doing the work assigned to them, but do make an effort to study and attend class. This study also found that students' priorities are not always aligned with their practices and/or values, particularly as related to work ethic, studying, and doing assigned work. Lower prioritization of note taking and attending class means a closer alignment between priorities, practices, and values, but does not contribute to overall academic success.

Introduction

Post-secondary institutions take student success seriously. Learners are supported throughout their undergraduate years with myriad systems, resources, and interventions, each designed to help students be successful in their studies. Increased efforts are being made to ensure quality learning environments that include "solid and effective teaching, strong levels of student engagement, deep learning, and value-added skills development" [1]. Despite these initiatives, the undergraduate engineering experience remains primarily lecture-based and teacher-centred, with more than half of all instructors concerned that their students are ill-prepared for the rigors of engineering [2]. A recent survey of engineering students confirms that their undergraduate classes are lecture-based and that learners are experiencing cognitive overload in these contentintensive lessons [3]. While institutions and engineering schools play an important role in supporting the success of their learners, students themselves have a unique and often individual perception of what is required for them to be successful.

This paper examines what students believe is necessary, and what they are actually doing to be successful in their engineering studies. It compares their beliefs to their actions and suggests ways that engineering schools might support those efforts.

Background

The Higher Learning Commission's 2018 report on defining student success suggests that approaches to student success fall along a spectrum ranging from an institutional data-driven completion-focused perspective to a more flexible framework of success from an individual student's view [4]. The report suggests that somewhere in the middle of this spectrum lies a framework with learners at the center where student success "is more than criteria or metrics – it is an organizational process and mindset around success for the students served, informed by a deep understanding of the learners, along with their active involvement in selecting solutions that work for them" (p 7).

Studies at the institutional end of the spectrum tend to focus on organizational and retention-driven aspects of student success with the goal of defining and implementing strategies to ensure students have the support required to be academically successful. York, Gibson and Rankin identify six components of academic success: academic achievement, satisfaction with the learning experience, acquisition of skills and competencies, persistence, attainment of learning objectives, and career success [5]. These components can be used to define tangible goals for student success initiatives within dedicated student success departments, faculties, and individual classrooms.

Moving to the far end of the student success spectrum, a series of interviews with students suggests success is "not just of good grades and steady progress toward graduation, but a holistic sense of fulfillment. They want to become strong candidates for careers in their chosen fields, emerge as competent and trustworthy adults, look back on their time without regrets, and make their mentors and family members proud" [6]. This means cultivating grit, striking a balance, nurturing curiosity, earning the respect of others, and finding purpose and fulfillment. The personal-ness of these aspirations is what makes it more difficult for institutions, faculties, and educators to support student success.

A student-centred lens at the middle of the student success spectrum considers what and how students approach learning. A literature review of more than 330 contemporary research studies identifies five student-centred dimensions that are vital to student success: (1) connectedness, (2) mindsets, (3) self-management, (4) professional identity, and (5) academic capabilities [7]. Focusing on the self-management dimension for which students themselves are responsible, Goodwin and Hein report that a "can-do" attitude, self-discipline, good study habits, and active engagement in the learning process are essential for student success [8]. Bean and Eaton suggest the ways students approach or avoid their studies can predict whether or not a learner will be successful [9], and Tangney and her team report that high self-control is a strong predictor of higher grades [10]. Studies of undergraduate engineering students identify similar factors including student ability, student background, disposition, and behaviour, and/or educational attributes and climate [11]. Work in progress even suggests that student success is as simple as "doing the work" [12].

Given that students indicate they want help improving their study skills [13], it is interesting to note that recent studies indicate that institutional interventions don't necessarily translate to better grades [14] [15]. Nudging interventions, where students are gently encouraged to apply effective study habits, did increase learners' willingness to work hard to get better grades, but didn't actually reduce the gap between the actual and intended number of hours dedicated to studying. This type of intervention also increased students' belief that hard work would improve their grades, but they appeared willing to accept lower grades rather than put in the extra work required to get higher ones.

A scan of the strategies that post-secondary institutions typically recommend for students to be successful includes those around developing academic skills (reading, writing, listening, test prep, time management), being a good student (preparing for, going to, and participating in class, regularly reviewing concepts and skills, doing and submitting assigned work) and getting involved beyond the classroom. Given that this support may or may not be useful, it seems the onus for success may lie in what learners themselves choose to do. This mixed method study explores what undergraduate engineering students are doing to be successful by asking three questions:

1. What strategies do engineering students use in order to be successful?
2. Is there a difference in the approaches used by exemplary, average, and struggling engineering students?
3. Is there a difference between what engineering students believe and what they actually do?

Methodology

Engineering students enrolled in one of Canada's smaller engineering schools were invited to complete an online survey that examined five student-driven factors commonly associated with student success: (1) use of class time, (2) completing assigned work, (3) note taking, (4) studying, and (5) overall work ethic. The survey was broken into two parts; a set of forced-choice questions measuring student success-related behaviours, and a set of Likert-style questions gauging beliefs about those behaviours and validating the forced-choice responses.

The forced-choice technique was selected to minimize the chances of students faking or biasing their responses [16]. Research shows that a survey with 20 three-item questions that combine positive and negative statements provides "very good levels of measurement accuracy" for applications that measure five distinct traits [16]. In this study, each of the 20 forced-choice questions directed students to order three statements, each from a different success-related factor, so that "the top statement is the one most like you and the bottom statement is the one least like you". Each question included two "positive" statements related to behaviours that support student success (e.g. *I ask questions in class if I don't understand something*) and one "negative" statement associated with behaviours that impede success (e.g. *I will miss class in order to study for a test or exam*), with the order of positive and negative statements varying from question to question. Each success factor appears in 12 different questions, eight with a positive statement and four with a negative statement. Seven of the fifteen Likert-style questions were used to measure students' beliefs about the importance of each of the five student-driven success factors (e.g. *Attending class is important for learning new concepts*). The next seven Likert questions measured students' behaviours and validated the forced-choice responses (e.g. *I regularly attend and stay focused in my classes*). The last Likert question asked students to rank the effectiveness of the strategies they themselves apply. Finally, a set of open ended questions allowed students to identify strategies they believe contribute to or impede their success.

Data Analysis

Students were recruited during the last twenty minutes of a scheduled theory class. 115 students were present during these recruitment sessions, 112 of whom signed consent forms each with a unique four-digit ID code. Of those students who agreed to participate in the study, 76 opened the online survey. It was completed by 70 students, four of whom provided an invalid ID code leaving 66 participants (57.4% of those approached). First year students make up 39% (N = 26) of the sample population, second year 11% (N = 7), third year 18% (N = 12), and fourth year 32% (N = 21). Students' sessional grade point averages (GPAs) were recorded for the semester immediately preceding the survey and their overall GPAs were recorded at the end of the following semester. Numeric GPAs were converted to alpha grades using the institution's conversion table, where an A is equated to a GPA 3.75 or higher, B from 3.0 to 3.74, and C from 2.0 to 2.99. A GPA that is less than 2 is equated with an F. The majority of students (59%) achieved a B-level GPA, 24% achieved an A-level GPA and the remaining 17% got C-level GPAs.

Analysis of the forced-choice data was based on the Thurstonian Item Response Theory (IRT) [16]. Traditional modeling of comparative measures can lead to distorted scale relationships that make it difficult to compare individual respondents. The Thurstonian IRT model minimizes this problem and is suitable for comparison of forced-choice data with any number of measured traits and any number of items per question. The process of converting student-ranked responses to the five factors of student behaviour is discussed in Appendix A.

RapidMiner Studio 9.3's Auto Model mode was used predict the classification of a student's grade based on the relative measures of student behaviour within the five factors. Nine machine learning models including Native Bayes, Generalized Linear Model, Logistic Regression, Deep Learning, Decision Tree, Random Forest, Gradient Boosted Trees (XGBoost), Support Vector Machines, and kMeans Clustering were built and validated.

Multiple regression analysis was performed to determine if a relationship exists between the five factors of student behaviours and the Likert-based student behaviour and belief responses.

Results

Frequency graphs for each of the Thurstonian IRT model resultant student behaviours are shown below. The predominance of negatively coded weights in Figure 1 through Figure 4 shows that overall, students place lower priority on attending and participating in class, doing assigned work, taking notes in class, and having good study habits. The high proportion of positively coded weights in Figure 5 shows that students prioritize maintaining a good work ethic.

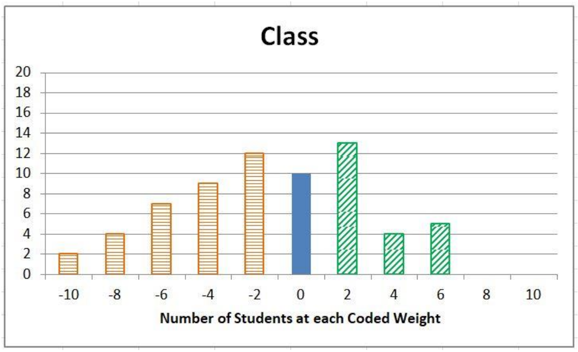

Figure 1: Students' prioritization of going to and participating in class

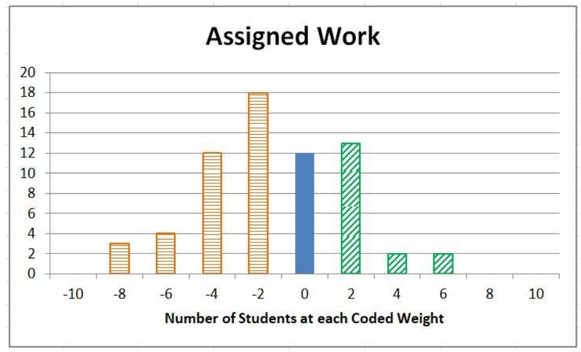

Figure 2: Students' prioritization of doing assigned work

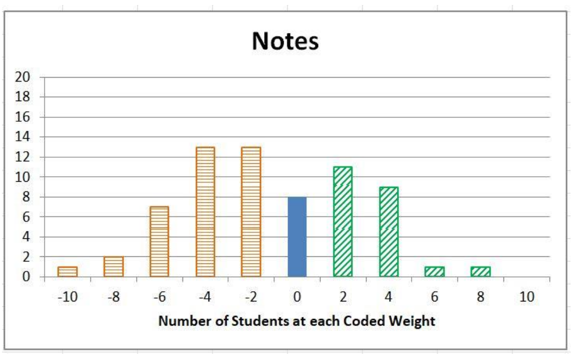

Figure 3: Students' prioritization of taking notes

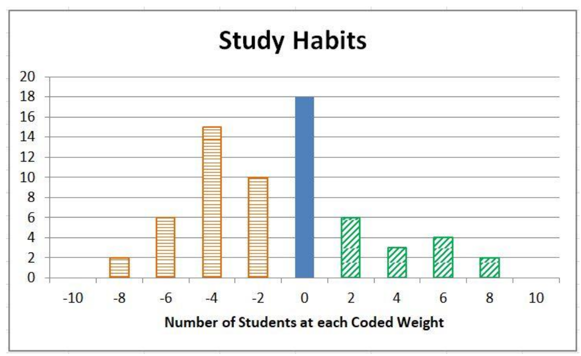

Figure 4: Students' prioritization of good study habits

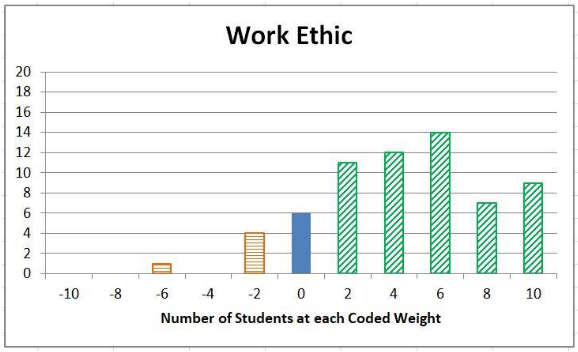

Figure 5: Students' prioritization of a good work ethic

A comparison of machine learning models of these five factors of student behaviour determined that the Gradient Boosted Decision Tree model, an adaptive reweighting and combining method, was the most accurate predictor of students' GPA (86.8%). No single factor had more than a weak correlation to students' GPA.

Figure 6 shows the model optimized for an A student. There is a moderately strong positive correlation (0.51) between students who complete assigned work and those who perform well academically. There are very weak correlations between doing well and students who don't take notes but do attend class.

Figure 7 shows the model optimized for a B student. There is a moderately strong correlation (-0.42) indicating students who do not have a good work ethic are more likely to perform at a B level. There are also very weak correlations between achieving an overall GPA of B and not studying or attending class.

Finally Figure 8 shows the model for a C student. There is a moderately strong correlation (-0.40) between students who do not do assigned work and those who get a C grade. There are weak correlations between achieving an overall GPA of C and studying and attending class.

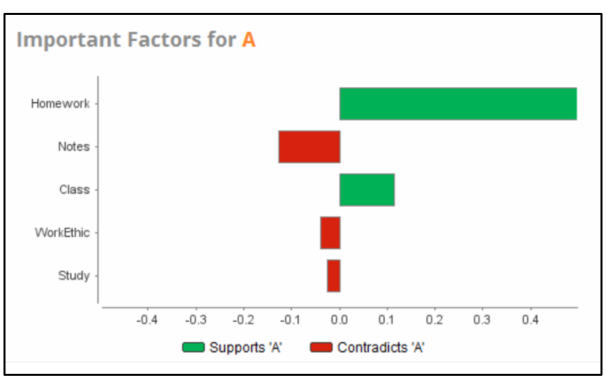

Figure 6: Gradient Boosted Tree model optimized for an A student

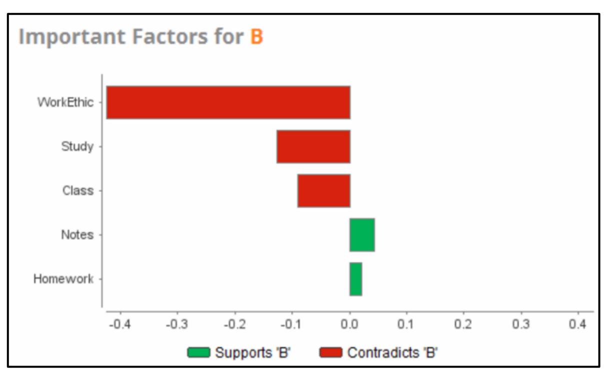

Figure 7: Gradient Boosted Tree model optimized for a B student

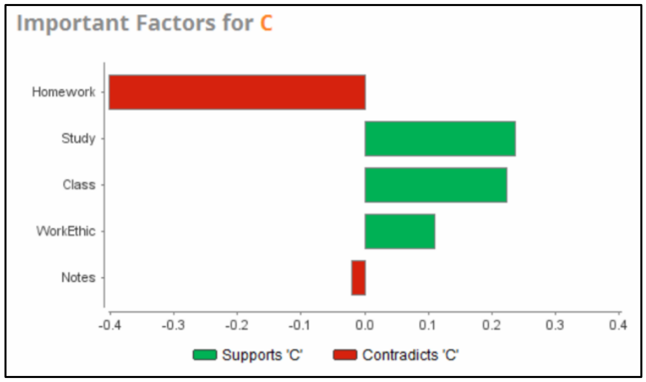

Figure 8: Gradient Boosted Tree model optimized for a C student

A multiple regression was computed to determine the independent contribution that each of the five behaviour predictors made to the overall GPA. The Pearson's r values showed that the students' inclination to do assigned work showed a moderately significant relationship with their overall GPA ($r = 0.39$, $p < .001$). For this sample, 15% of the variability in overall GPA was accounted for by its relationship with doing assigned work. A linear regression was computed using homework to predict GPA and was significant, $F(1,64) = 11.19$, $p < .001$. The regression equation $Y' = 0.078X + 2.178$ shows that overall GPA increased 0.078 units for each unit that the assigned work behaviour increased. The standard error of the estimate for predicted GPA was 0.60. No other behaviour predictor showed a significant correlation with GPA.

Three strong positive correlations were also found between forced-choice behaviour predictors and the Likert behaviour and value responses (see Figure 9). The first showed a strong positive relationship between students who believe taking notes is valuable and those who do take notes ($r = 0.72$, $p < .01$). The second showed a strong positive correlation between students who believe attending class is important and those who do attend ($r = 0.66$, $p < .01$). The third showed a strong positive relationship between students who indicate they take notes in class and their notetaking behaviour predictor ($r = 0.55$, $p < .01$). Moderate positive and negative correlations are also shown in Figure 9.

Discussion

This study explored the types of strategies that separate more successful undergraduate engineering students from those who struggle academically. It highlights three key findings:

1. students who do assigned work are more likely to be more successful
2. there are distinct success-related behaviours associated with different levels of academic success, and
3. students' priorities are not always aligned with their practices and/or values.

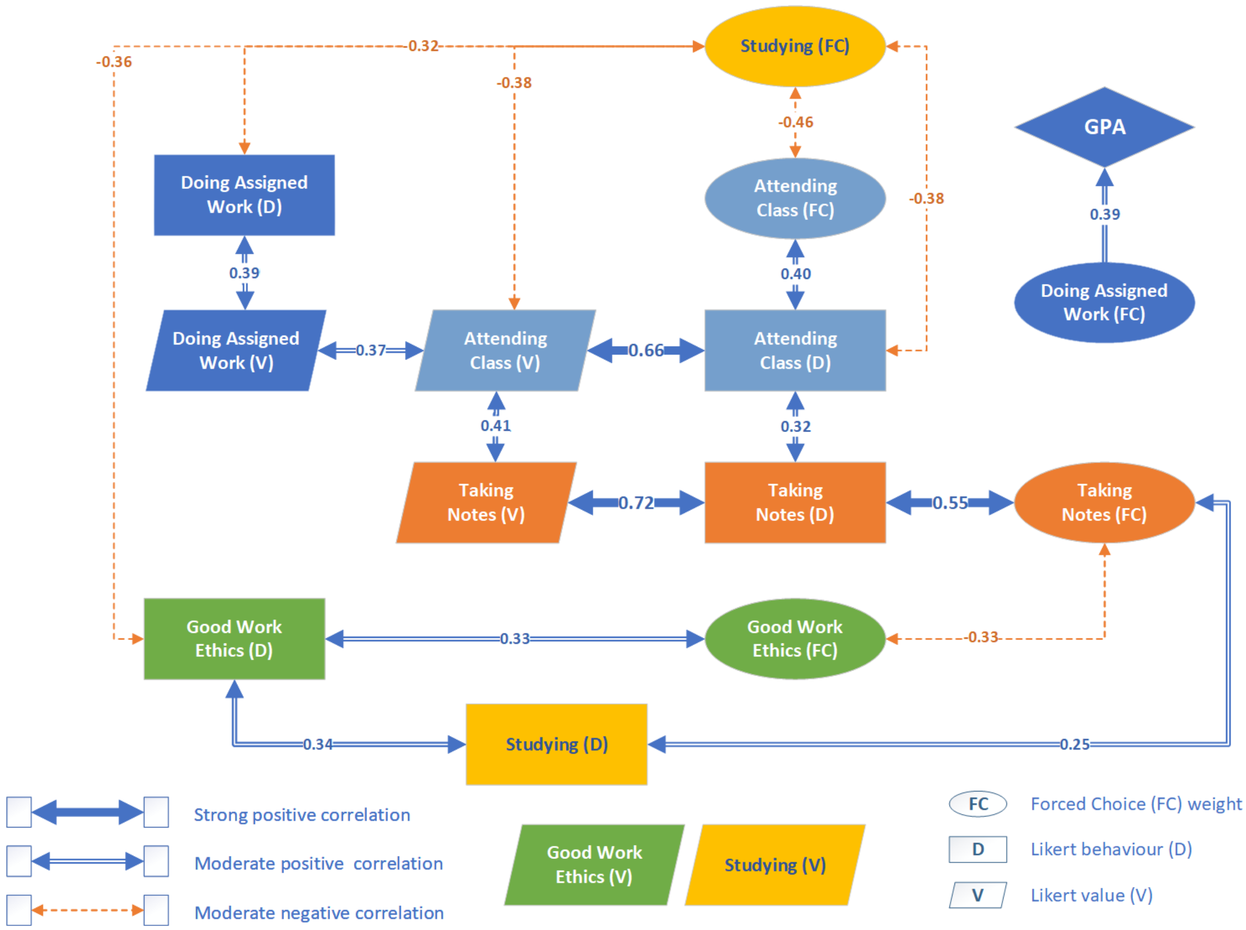

Figure 9: Correlations between forced-choice and Likert behaviour and value responses

It is apparent from the literature that students who apply evidence-based learning strategies to their studies are more likely to be successful [8] [9] [10] [17]. Results of this study indicate that, while most undergraduate engineering students prioritize a good work ethic (92.4%), fewer than half (43.9%) prioritize doing the work they are assigned. This study showed, however, that making a habit of doing assigned would be more beneficial and increase engineering students' likelihood of being successful in their studies. This finding directly supports van den Bogaard's work that established a link between doing the work and succeeding in undergraduate engineering programs [12]. It also aligns with learning studies research that suggests regular and deeper learning occurs when students engage with content in meaningful ways [18] [19]. Assigning work that selectively focuses on the development of key concepts and skills will provide students with opportunities to review, retrieve, apply, practice, and integrate new knowledge and skills into their own knowledge constructs [17].

The classification portion of this study identified distinct predictors of students' overall academic achievement. It validated the above correlation between academic success and doing assigned work, establishing that doing assigned work is the strongest indicator that students will maintain an A-level GPA. The success-related behaviours most closely associated with a B student are a less than ideal work ethic, ineffective study techniques and not attending class. These students do, however, take notes when they attend class, and do some of the assigned work. The most important factor in predicting C students is their failure to do assigned work. These students prioritize studying but are inefficient because they have done few, if any, of the assignments and have minimal or poor notes from class. The reasons students choose less than optimal learning strategies were not explored in this study, but cognitive overload, where the capacity of working memory is exceeded, may be a factor in whether or not they are able to be effective learners [20]. Efforts to reduce cognitive load, such as presenting new concepts in smaller chunks, and modeling, scaffolding and providing myriad opportunities for practice, may remove some of these challenges.

The literature shows that students want to be successful in their studies [13] but do not always apply the best practices even when encouraged [14]. This study extends that work, adding that students' priorities do not always aligned with their practices and/or values. The majority of students in this study (94.2%) put a high priority on work ethic. Alignment was found between the prioritization of work ethic and their self-reported behaviours, but not between either their work ethic-related priorities or practices and what they value. Studying was prioritized by half of the students (50%), but again there was no alignment between this level of priority and either the students' study practices or values. Nor was there an alignment between their study-related practices and values. Similarly, doing assigned work was prioritized by about half the students (43.9%) but there was no alignment at all in their priorities, practices and values. This lack of alignment indicates there may be personal or institutional factors interfering with students' abilities to achieve as well as they might.

Note taking and attending class, the remaining two behavioural factors, displayed slightly better alignment. Both exhibit alignment between the students' priorities and the students' practices; the students reported that they attend class and take notes in accordance with the priority they placed on each. Unfortunately, more than half of all students (notetaking at 54.5% and attending class at 50.5%) placed a low priority on these learning strategies, so the students may not exhibit these behaviours often enough to be beneficial. The students' practices and values also aligned for both factors indicating they did what they believed was best for their success. There was, however, no alignment between students' prioritization and their values. Early interventions that help balance students' priorities, supported with ongoing reflective practice, may help bring students' priorities, practices and values into alignment.

Limitations

We believe that the participants in this study represent all Canadian undergraduate engineering students, but recognize they are not statistically representative. The findings of this survey may have a bias associated with non-response. Students who chose to complete the survey may have different views from those who did not. It is also not known what other factors may have contributed to response or non-response. As a result, these findings should be considered in the context of the limitations of this study.

Conclusions and Future Work

Evidence-based student success-related initiatives abound in higher education. This research adds insights that can help engineering educators recognize and develop student behaviours that lead to academic success.

This research lays the groundwork for a number of further studies. Examination of why engineering students choose less than optimal learning strategies could help shape engineering-specific interventions to increase students' academic success. Additional work could be done to determine if efforts to align students' priorities, practices and values has a positive effect on student success.

It is hoped that adding this research to the existing body of evidence on student success will encourage engineering educators to recognize the effect that priorities, practices, and values have on their students' academic success, and provide opportunities that support deeper learning both in and beyond the classroom.

Acknowledgements

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Appendix A: Thurstonian Item Response Theory (IRT) Modeling

Survey responses were returned as ranks where '1' indicated students that felt it was most like them, '2' was in the middle, and '3' was least like them. These ranks were compared to one another and coded using the criteria shown in Table 1.

Table 1: Criteria used to code forced-choice ranks

1st	ranked	2nd	code
P	higher	P	1
P	lower	P	-1
P	higher	N	1
P	lower	N	1

1st	ranked	2nd	code
|N|	higher	P	-1
|N|	lower	P	-1
|N|	higher	|N|	-1
|N|	lower	|N|	1

Say, for example, that the first question asked students to compare statements from the first (positive), second (negative), and fifth (positive) student-driven factors (presented in that order). The first statement Student N ranked them 2, 1, 3, meaning that the second statement was most like them, and the third statement was least like them. Since there are five factors (n = 5) there are ten binary outcomes ($\tilde{n} = \frac{n(n-1)}{2}$), the first factor ($F_1$) compared to each of the other four, the second factor (F_2) compared to the remaining three, the third factor (F_3) compared to the remaining two, and the fourth factor (F_4) compared to the last one (F_5). Student N ranked F_1 second, F_2 first, and F_5 third.

F_1 is compared to F_2 using Table 1. Since the first statement (F_1) is positive and the second (F_2) is negative, F_1F_2 is coded as 1 (see Table 2). Neither F_3 or F_4 are ranked in the question, so both F_1F_3 and F_1F_4 are coded as 0. Since the first statement (F_1) and the third (F_5) are both positive, and F_1 is ranked higher than F_5, F_1F_5 is coded as 1. Next F_2 is compared to remaining factors. Since F_3 and F_4 are not included in the question, both F_2F_3 and F_2F_4 are coded as 0. F_2 is compared to F_5 and since F_2 is negative and F_5 is positive F_2F_5 is coded as -1. Since F_3 and F_4 are not included in the question the remaining cells are coded as 0.

Table 2: Sample Coding for Forced-Choice Sample Question (Latent Utilities Vector)

F_1F_2	F_1F_3	F_1F_4	F_1F_5	F_2F_3	F_2F_4	F_2F_5	F_3F_4	F_3F_5	F_4F_5
1	0	0	1	0	0	-1	0	0	0

The IRT model considers these codes to be a 1x10 vector of latent utilities. This vector is multiplied by a 10x5 ($\tilde{n}xn$) design matrix where each column corresponds to one of the five (n) factors and each row to one of the ten ($\tilde{n}$) pairwise comparisons (see Table 3).

Table 3: Design Matrix for Five Factor IRT modeling

1	-1	0	0	0
1	0	-1	0	0
1	0	0	-1	0
1	0	0	0	-1
0	1	-1	0	0
0	1	0	-1	0
0	1	0	0	-1
0	0	1	-1	0
0	0	1	0	-1
0	0	0	1	-1

The resultant 1x5 vector of latent difference responses shown in Table 4 contains the weighted values for this question. This gets added to the weighted values of all other forced-choice questions to produce a relative measure of the student's behaviour within each of the five factors.

Table 4: Latent Difference Responses for Forced-Choice Sample Question

2	-2	0	0	0