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Changes in Non-Cognitive and Affective (NCA) Factors in Engineering and Computing Students: A Longitudinal Study of Mechanical Engineering Students

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ABSTRACT

CONTEXT

Numerous non-cognitive and affective (NCA) factors (e.g. Personality, Identity, Mindset, etc.) relate to student success in academics. Some factors or collection of factors relate positively to academic success while others do not. In addition, many NCA factors are malleable, creating an opportunity for educators to improve student academic performance with the use of targeted interventions. Understanding how factors change over time and the causes of those changes can provide insight to educators looking to improve individual academic performance in engineering and computing students.

PURPOSE OR GOAL

As a first step in determining to what extent NCA-based interventions can improve academic performance and the perceived quality of the undergraduate experience, we seek to know how NCA factors of a group of Mechanical Engineering students change over time. We posit that some NCA factors will not change (some constructs are not considered malleable) and some factors will change at identifiable points in the students' experience.

APPROACH OR METHODOLOGY/METHODS

A comprehensive and validated survey instrument measuring 28 NCA factors was given to engineering and computing students (n>2000) at a large state university in the United States for three consecutive academic years. A small group (n=47) took the survey in each of their first three years of university studies. Looking at these survey responses, we performed a repeated measures analysis of variance to determine longitudinal changes in NCA factors.

ACTUAL OR ANTICIPATED OUTCOMES

Analysis indicates that six of the NCA factors change significantly for the Mechanical Engineering students over time. These include *Engineering Identity*, *Motivation by Expectancy*, two measures of *Stress*, *Belongingness* and *Neuroticism*. There may be a slight increase in responses for the two measures of *Stress* and *Neuroticism* over time. However, for *Motivation by Expectancy*, *Belongingness* and *Engineering Identity*, there is evidence of a significant decrease in these factors over time. This may be of particular concern since decreases in these three factors correlate with decreased success.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

NCA factors can predict elements of student success in engineering and computing students. Some malleable NCA factors change over time and targeted interventions can be developed to change these student beliefs and attitudes to foster greater academic success. Results of this work are being used to plan the scope and timing of these interventions. Some beneficial NCA factors decrease during a student's experience, which is troubling and indicates that perhaps larger systemic changes need to be considered as well.

KEYWORDS

Non-Cognitive Factors, Academic Success, Longitudinal Study

Introduction

The U.S. National Science Foundation (NSF) funded Studying Underlying Characteristics of Computing and Engineering Student Success (SUCCESS) survey was created and validated to assess 28 non-cognitive and affective (NCA) factors in engineering and computing science students. Many of these NCA factors have independently been shown to relate to student success in college. The SUCCESS survey has now assessed over 4,000 engineering students in the United States over the course of four years and has provided valuable insight into the NCA profiles that exist within computing and engineering students (Scheidt et al., 2018; Scheidt et al., 2021; Perkins et al., 2021). Typically, student potential and preparedness for undertaking engineering and computing studies are determined via high school grade point averages and standardized test scores; however, these have been shown to be poor predictors of student performance trajectories over time. One purpose of the SUCCESS project is to utilize the information gathered through survey administration to explore student performance through new lenses that challenge traditional assessment of student potential. Another goal of the SUCCESS project is to identify student populations that may be at risk by using their NCA profiles to guide initiatives in support of those students and have a positive impact on broadly defined measures of student performance. A major research question of the project is to determine to what extent NCA-based interventions improve academic performance and the perceived quality of the undergraduate experience in engineering and computer science. Prior to determining what interventions should be developed, we are using longitudinal data to see if student NCA profiles change without interventions. In other words, do student NCA profiles change simply from their academic and life experiences in college and if so, when during their experiences do the changes occur? This knowledge can not only guide the selection and design of interventions, but can also provide a sense of when during the course of a student's academic experience would be the best time for the intervention. In this work, we explore the results of a longitudinal study of Mechanical Engineering students who took the survey in each of their first three years at University.

Background

Although the SUCCESS survey measures 28 separate constructs, only six proved to be relevant to this work (See Results). A description of each of these six constructs follows. For descriptions of all constructs and the complete set of questions in the SUCCESS survey, please see Scheidt, Godwin et al (2018). The cited study also reviews all constructs and the validity of the survey questions in the instrument. Each construct is measured by a set of questions that students answer on a seven-point Likert scale.

Belongingness: The sense of a student belonging to an academic field is important to engineering and computing students. Marra et al (2012) reports that belonging is a major contributor to students' decision to leave engineering. This basic human need must be met for human fulfilment in an occupation (Maslow, 1943). This construct is measured through six instrument items with high scores indicating that students have a greater sense of belonging in their academic community. The sense of belonging can be influenced by the academic environment and is therefore considered malleable.

Identity – Interest: Identity in general is defined as "being recognized as a certain 'kind of person,' in a given context" (Gee, 2000). When a student's identity matches with their academic experience, this can lead to better persistence and retention in engineering (Godwin et al, 2016). The SUCCESS survey measures three different subscales of *Identity* with the *Interest* subscale important in this study. This subscale measures a student's enjoyment of and their desire to learn a subject (Godwin, 2015), with higher ratings corresponding to a greater sense of engineering or computing identity. One's identity is developed and changes over time and is influenced by an academic setting and is therefore considered malleable.

Motivation – Expectancy: For the SUCESS survey, we measured motivation using a future time perspective, by examining how students develop long-range behaviours to achieve distant goals. The survey measures motivation with five different subscales and the *Expectancy* subscale is significant in this work. Five survey items measure *Motivation by Expectancy*, which is a student's belief that they will do well in their endeavours. In general, higher motivation is linked to academic persistence and better performance in engineering. This construct is malleable and higher motivation can be fostered in students by connecting coursework to future goals and by encouraging students to believe in their ability to succeed (Ponton et al, 2001).

Student Life Stress – Reactions: The SUCCESS survey measures five dimensions of student stress with *Reactions* and *Changes* significant in this current work. The *Reactions* dimension measures a student's direct reaction to stress including physical reactions (e.g., sweating, headaches) and mental state (irritability, anxiety, fear, etc.). Higher scores on this measure relate to greater stress. Stress can greatly influence student academic performance, both positively and negatively (Gadzella et al, 2012). There are several ways students can learn to moderate stress, including learning better time management skills or through improved mindfulness (Chiesa and Serretti, 2009).

Student Life Stress – Changes: Another dimension of *Student Life Stress* is the stress caused by changes such as disruption of goals, unpleasant experiences or many life changes occurring at the same time. This is measured using three items in the survey.

Neuroticism: This personality trait is one of the Big-Five (McCrae and John, 1992), which also includes *Conscientiousness*, *Extraversion*, *Openness to Experience* and *Agreeableness*. *Neuroticism* relates to anxiety, personal insecurity and possibly irritability or hostility. Three items are used to measure this dimension with higher scores correlating to a stronger neurotic personality trait. Neuroticism has been shown to negatively relate to academic satisfaction (Trapmann et al, 2007). Personality traits in general may change throughout life over long time-scales and in response to life events, but are not considered as malleable as the other traits listed above.

Methods

Data Collection

The survey was given via paper copy to students starting in the 2017-2018 Academic year to the majority of first year students in all engineering and computing majors at California Polytechnic State University (Cal Poly), a large undergraduate focussed public school on the west coast of the United States. Using the paper copy and having the students take the survey in their courses ensured a high response rate. In the subsequent years, the majority of all Mechanical Engineering students took the survey. From this dataset, we identified 47 students who had taken the survey in each of the first three years at the University. It should be noted that all surveys were taken prior to the COVID-19 pandemic and therefore this did not influence the results.

Participants

The demographic profile of participants who took the survey in each of their first three years is given in Table 1. This demographic profile is reflective of the Cal Poly Mechanical Engineering department's student body.

Table 1: Demographic Profile of Mechanical Engineering Participants*

Race/ethnicity	Number of participants	Percentage
White	24	52.2%
Asian	7	15.2%
Hispanic or Latinx	5	10.9%
Black or African-American	0	0.0%
Native American	1	2.2%
Multi-racial	6	13%
Declined to answer	3	6.5%
Gender		
Female	15	32.6%
Male	31	67.4%

* Demographic information was voluntary and provided by 45 of 47 students in the sample

Data Analysis

To determine whether there was a difference in responses for each student and construct over the span of their first three years in school, a repeated measures analysis of variance (ANOVA) was performed using the statistical software R. There was one test per construct, resulting in 28 repeated measures ANOVA tests. Each ANOVA tested for differences in a student's score for a given construct over a three-year period. To adjust for multiple tests, the Benjamini and Hochberg False Discovery Rate (FDR) method (Benjamini and Hochberg, 1995) was utilized to identify as many significant comparisons as possible while also controlling the false positive rate. With the FDR method, each resulting p-value was adjusted and then compared to a significance level of 0.05. This means that the probability of making at least one false discovery would be at most 5%. Of the 28 repeated measures ANOVA tests, six tests found significant differences. For these six, a pairwise comparison using the same FDR adjustment was then conducted to identify which years were different from one another.

The most common indictor of academic success is Grade Point Average (GPA), and this variable is used in this study. Next, we investigated the relationship between GPA and each of the significant factors with a correlation test (Spearman's method) to evaluate the association of GPA and each of the six significantly changing constructs for each year of school. For each school year, a student's GPA was calculated from their official transcript and this value was tested against each of the six NCA factors. This test was repeated for each of the three years of study under consideration (thus the GPA tested was the year's GPA rather than the cumulative GPA).

Results

The repeated measures ANOVA indicated that six of the factors showed a statistically significant change during the first three years at University: *Belongingness* (p-value=0.028), *Identify - Interest* (p=0.028), *Motivation - Expectancy* (p=0.028), *Student Life Stress – Reactions* (p=0.028), *Student Life Stress – Changes* (p=0.036) *and Neuroticism* (p=0.048). Figures 1-3 show the box plots of each factor over the three years. In Figure 1, we see that scores for both *Belongingness* and *Identity – Interest*, decrease over time. For both factors, the temporal differences are statistically significant between the first and second year and between the first and third year, but not between the second and third year (Table 2).

We also see similar temporal differences for three other factors (Table 2). Both *Student Life Stress – Reactions* and *Student Life Stress – Changes*, scores tend to increase over time (Figure 2) whereas for *Motivation – Expectancy*, scores tend to decrease over time (Figure 3). Again, for these factors the changes are significantly different between the first and second, and the first and third years, but not between the second and third years of studies.

Finally, in Figure 3, we see that students' mean scores in *Neuroticism* increase at first and then decrease over time, with the largest difference being between first and second year. Although, the repeated measures ANOVA produced a significant p-value (p=0.048), a separate paired t-tests for each combination of years of study found no statistically significant difference (Table 2). This finding suggests that the repeated measures ANOVA produced an anomalous significance, perhaps due to the broad distributions in the scores for each year.

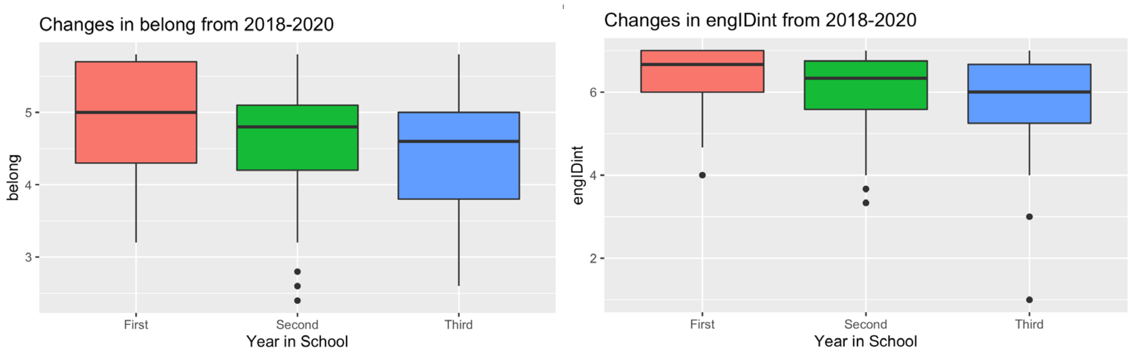

Figure 1: Box plot for changes in *Belongingness* (left) and *Identity – Interest* (right) for the first three years at University.

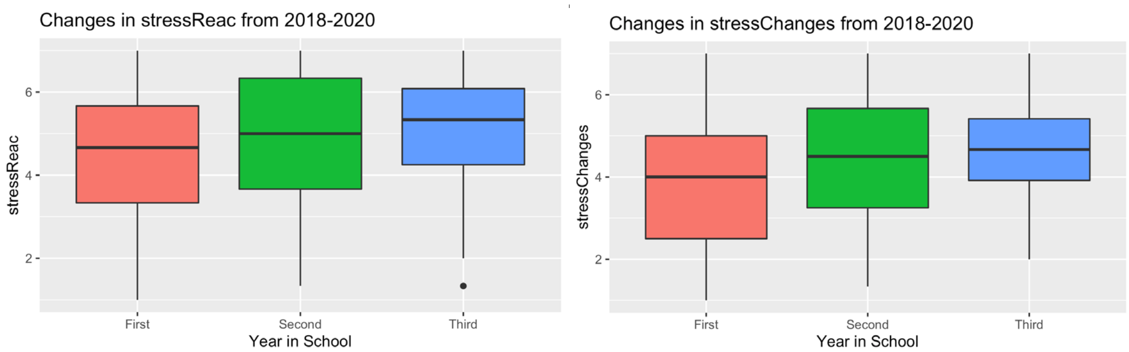

Figure 2: Box plots for changes in *Student Life Stress – Reactions* (left) and Student Life Stress – *Changes* (right) for the first three years at University.

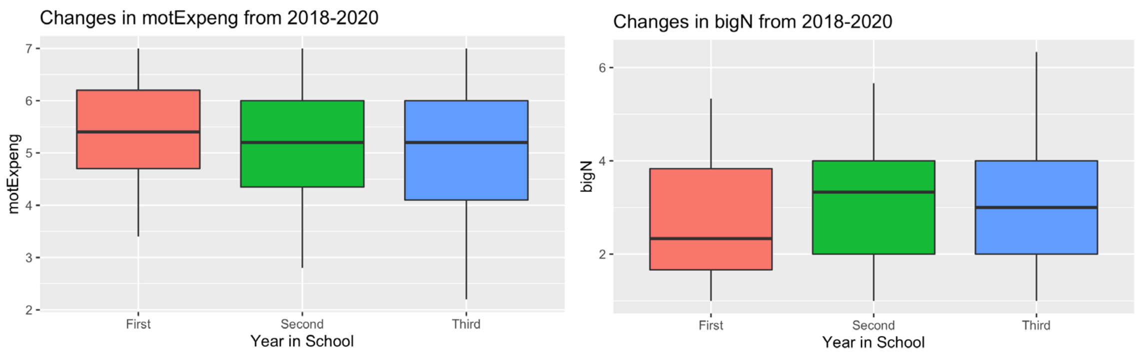

Figure 3: Box plots for changes in *Motivation – Expectancy* (left) and Neuroticism (right) for the first three years at University.

Table 2: Pairwise Comparison Results for Significant Factors

Factor	School Year Comparison	Adjusted P-value
Belongingness	First – Second	0.033*
	First – Third	0.015*
	Second – Third	0.463
Identity – Interest	First – Second	0.017*
	First – Third	0.005*
	Second – Third	0.212
Student Life Stress – Reactions	First – Second	0.037*
	First – Third	0.024*
	Second – Third	0.719
Student Life Stress – Changes	First – Second	0.024*
	First – Third	0.024*
	Second – Third	0.614
Motivation – Expectancy	First – Second	0.043*
	First – Third	0.043*
	Second – Third	0.621
Neuroticism	First – Second	0.062
	First – Third	0.062
	Second – Third	0.610

* The mean difference is significant at the 0.05 level

The correlation tests between GPA and each of the five significantly changing factors (neuroticism is no longer considered based on results in Table 2) showed that three factors appear to have a significant association. As shown in Figure 4, there is a negative correlation, for all three school years, between GPA and *Student Life Stress – Changes* and *Student Life Stress – Reactions*. These negative associations indicate that the higher the score for either of these stress factors, the lower the GPA. On the other hand, for *Belongingness*, there is a significant positive association with GPA, but only during the third year at University. In other words, during students' third year of school, the higher a student's sense of *Belongingness*, the higher their GPA. It is important to note that correlation does not mean causation and that lower or higher NCA factor scores do not necessarily cause lower or higher GPAs. We also note that Figure 4 demonstrates the relatively broad distributions of GPA across factor scores for all three factors.

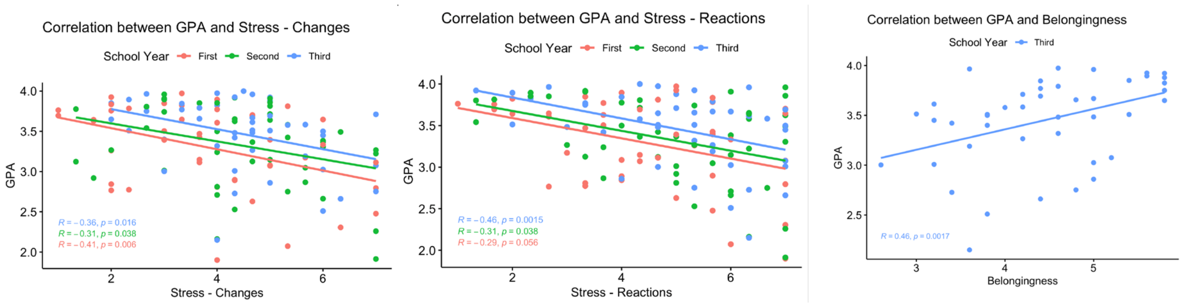

Figure 4: Scatterplots of GPA vs *Student Life Stress – Changes, Stress-Reactions and Belongingness*

Discussion

In general, we found that five of six factors (excluding Neuroticism) that changed significantly over time shared several traits in common. First, each factor trended in the direction that previous studies have found to be correlated with lower student success. While worrisome, students obviously are still capable of succeeding in the program and this finding suggests opportunities for helping students to not only succeed but to thrive. Second, all five factors were found to be significantly different between the first and second years and between the first and third years, but not between the second and third. This perhaps suggests that the major changes are occurring between the first two years of engineering studies and that targeted support to students should occur then. Sadly, it is well established that students usually leave engineering programs during this time, which adds further impetus to supporting students during this critical time period. Below we discuss the implications from the finding for each specific factor.

Belongingness: The decrease in students' sense of belongingness is important because a lack of belonging is one of the top reasons students leave engineering (Marra et al, 2012). In the science and engineering context, belongingness is also strongly correlated with student success (Holmegaard et al., 2014; Schar et al., 2017; Seymour and Hunter, 2019). We found that during students' third year of school, a higher sense of belongingness is correlated with higher GPAs, further emphasizing the importance of this factor to students' success. At Cal Poly, students do take introductory courses in Mechanical Engineering their first year; however, the majority of their academic work during this period is in basic math and sciences, which are not taught by engineering departments. The number of engineering classes increases in both the second and third year. This may explain some loss of belongingness as students may fail to identify with their major until they take more classes. If this is true, we would expect an increase in belongingness from the third to fourth year, which has not yet been evaluated. Engineering programs may consider hosting events that offer community-building experiences that may aid in increasing students' sense of belongingness with the goal of increased retention and academic performance.

Identify – Interest: Similar to *Belongingness*, students' engineering identity, more specifically their interest and enjoyment in learning about their major, decreased over the first three school years. These two findings are consistent since students whose identities don't align with their disciplinary roles may feel a decreased sense of belonging. It is possible that the decrease in *Belongingness* is also associated with the decrease in students' desire to learn more. Several recent studies have pointed to the importance of engineering identity to student success, especially for the retention of minoritized students (Ross, Huff & Godwin, 2021; Pierrakos et al., 2009). To counteract this decrease in identity, many interventions can be implemented. For example, instructors can be encouraged to provide more positive reinforcement and refer to students as engineering professionals rather than 'in-training' professionals. Additional actions include offering more projects that align with student interests and providing equal educational opportunities.

Significant Stress Factors: From the results, we found that over the first three years of study, Mechanical Engineering students' stress due to changes and their reactions to stress increased. Increased stressors could be because the curriculum for Mechanical Engineering students increases in difficulty during each year, with the third year typically considered the most difficult. With courses becoming more difficult, it becomes harder for students to manage all their work, thus affecting ability to manage time, which then impacts stress levels. It is also typical at Cal Poly for many first-year students to move out of the dormitories between the first and second years. This may also increase the level of stress students feel as they become more responsible for taking care of their personal needs (paying rent, acquiring and cooking food, managing transportation, etc.). This increase in stress and reactions to stress may have implications on student performance, as these two factors are negatively associated with GPA (see Figure 4). Discovering these trends about stress opens a window of opportunity for how to improve students' success. One possibility to help students in this area includes improving students' overall mindfulness, time management skills and providing increased levels of support for their courses.

Motivation – Expectancy: Past research has shown motivation to be a powerful factor in several aspects of student success (Guay et al., 2000; Matusovich et al., 2008). Our results show that students experience a decrease in motivation over the years, meaning that students are less likely to believe they will succeed in their future endeavors. Again, this decrease may be a result of the increasing difficulty in schoolwork each school year. It is possible that as the curriculum gets more difficult, students feel more challenged, thus feeling more discouraged in thinking they will do well in the future. As an intervention, faculty could encourage students to view their academic struggles as a means to grow, while also teaching students how to confront difficult assignments, so that they do not feel discouraged.

Conclusions and Future Work

NCA factors can predict elements of student success over time in engineering and computing students. It is possible to change malleable factors through targeted interventions that change student beliefs and attitudes toward their work, generating positive changes and perhaps helping students to thrive during their studies. This work reveals changes in NCA factors of students over their first three years of study without any intervention. We will be adding fourth year data shortly to extend our longitudinal dataset and complete a student's academic career. These preliminary results indicate that students' sense of Belongingness and Engineering Identity are prime candidates for intervention starting in the first year of studies. Work on those interventions has begun and will be piloted in the 2021-2022 academic year. For example, we are currently testing a values affirmation intervention (McQueen and Klein, 2006) and posit that an effective implementation will boost students' engineering identity, motivation by expectancy and belongingness. In addition, our results indicate that student stress levels may be having a negative impact on academic performance. We will also test interventions that help students better manage and minimize negative aspects of stress. Finally, the fact that certain important NCA factors are changing for students will lead to department-wide discussions about the need of systemic change to increase student success.

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