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Tracking SUCCESS in Mechanical Engineering Students: Update on a Longitudinal Study of the Role of Non-Cognitive and Affective (NCA) Factors

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Abstract

Previous studies have shown that many non-cognitive and affective (NCA) factors (e.g. Engineering Identify, Belongingness, Mindset, etc.) are related to student academic success. The NSF-funded Studying Underlying Characteristics of Computing and Engineering Student Success (SUCCESS) project is exploring the role that NCA factors play in retention and broad definitions of success for undergraduate engineering and computing students. This paper presents work completed through year five of the collaborative SUCCESS project. To date we have: 1) Generated NCA profiles of engineering and computing students by deploying the SUCCESS survey to a national cohort of engineering and computing students and 2) Explored the academic performance through time of Mechanical Engineering students at a large undergraduate focused public university to see how this performance relates to NCA profiles. In this project update, we present the results of a fourth year of longitudinal data collection of NCA factors and how they relate to academic performance for Mechanical Engineering students. This completes many of their undergraduate academic careers and preliminary results point to the importance of students' sense of Engineering Identity and Belongingness to their academic success. We further explore some of the extracurricular activities that students engage in that might impact these factors. Lastly, we will provide an update on the preliminary results of targeted interventions intended to improve academic performance through influencing malleable NCA factors in an effort to improve student outcomes.

Background

Predictive models for student academic performance in engineering and computing majors often rely on cognitive measures such as standardized test scores (SAT, ACT) or high school grade point averages. Unfortunately, these cognitive measures do not do a sufficient job of predicting achievement for most students [1-3]. Recently many researchers have examined non-cognitive and affective (NCA) variables (such as engineering *Identity* or *Belongingness*) and how they relate to student success. Our research seeks to fill in gaps of our understanding of how NCA factors and NCA profiles of students relate to and can be used to support academic success in engineering and computing students.

The NSF-supported SUCCESS project is a collaboration between three Universities: Purdue University, a large research-oriented institution, California Polytechnic State University – San Luis Obispo (Cal Poly), an undergraduate focused institution and the University of Texas at El Paso, a large research-oriented, Hispanic serving institution. The three overarching questions that guide this project are as follows:

- RQ1. What are the NCA profiles of engineering and computing students, and to what extent do profiles vary by institution, academic program, demographics, or over time?
- RQ2. In what ways are NCA factors predictors of academic performance, and how do they mediate a student's response to academic or personal obstacles they may face?

- RQ3. To what extent can NCA-based interventions improve academic performance and the perceived quality of the undergraduate experience, and how do students at different institutions experience those interventions?

The main tool that drives this research is the SUCCESS survey. Details of the survey construction, validation and the 28 NCA factors it measures can be found in references [4-6]. To answer RQ1, work at Cal Poly over the last four years has focused on creating a longitudinal dataset of survey responses from Mechanical Engineering students who are asked each year to take the survey. This not only allows a view of the NCA profiles of our students, but we can track how malleable NCA factors may change during student's university careers. By appending course grades to the survey dataset, we can also begin to answer RQ2. Finally, work to answer RQ3 has involved the testing of interventions at Cal Poly on cohorts of Mechanical Engineering students. This paper provides an update on the work at Cal Poly through the fifth year of the SUCCESS project [7].

After piloting an initial version of the SUCCESS survey at the three project institutions in the 2016-2017 academic year, final Scantron and Qualtrics® versions of the tool were given to engineering and computing students (n=3740) at 17 ABET accredited institutions in the United States. Using this data, Scheidt et al. [8] used 2339 valid surveys to perform a cluster analysis. He found that engineering students' NCA profiles fell into four discernable clusters. These include:

- Cluster 1: The Typical Cluster (n = 832). Members of this cluster had factor means that were all similar to the overall sample mean.
- Cluster 2: High Positive NCA Factors but with a *Fixed Mindset* (n = 500). The members in Cluster 2 generally scored high in many of the factors, with many statistically different from all other clusters.
- Cluster 3: Unconnected and Closed Off (n = 311). Members of this cluster displayed several factors that correlate to lower student success, including significantly lower means for *Engineering Identity: Interest*, *Belongingness*, *Expectancy*, *Instrumentality*, and *Connectedness*. Members of this cluster may include students who do not identify with engineering as a profession or as an academic field of study.
- Cluster 4: Without Feeling of Support from Faculty and Peers (n = 94). Cluster 4 has the fewest members and displays strongly negative values for several NCA factors that may predict lower student success. Members of this cluster scored lower than all other clusters for *Engineering Identity*, *Instrumentality*, *Perceptions of the Future*, *Expectancy*, *Belongingness*, *Agreeableness*, and *Perceptions of Faculty Support*.

Data Collection

At Cal Poly data collection began in the 2017-2018 academic year using the Scantron version of the survey given to mostly Mechanical Engineering students (n=321). During the next year, nearly every first-year student in the College of Engineering at Cal Poly and most Mechanical Engineering students were surveyed. Over the next two years, surveys were focused on Mechanical Engineering students to build out a longitudinal dataset. Prior to March 2020, paper copies of the surveys were given largely in class settings to maximize response rates. After

March 2020, surveys were given electronically using the Qualtrics® version due to the Covid-19 pandemic with lower response rates. Surveying is continuing through the 2021-2022 academic year with the online version but given in a classroom setting to increase the response rates. Table 1 shows survey completion over the last four academic years and the planned completion for this year. Academic performance data of each survey respondent has been appended to survey results along with student conduct data allowing us to track academic performance and to investigate how students might negotiate obstacles in the academic setting. The data is de-identified to protect the anonymity of the survey respondents.

Table I: Information on the surveys completed

Academic Year	Surveys Completed	Notes
2017-2018	321	Mostly Mechanical Engineering (M.E.) students
2018-2019	1253	All Engineering First Year students and Most M.E.'s surveyed
2019-2020	530	Only M.E. students surveyed
2020-2021	499	Only M.E. students via Qualtrics
2021-2022	900 (in progress)	Only M.E. students via Qualtrics

Grade Point Averages by Cluster Membership

As previously reported [7,9], tracking of Cal Poly students' academic performance over three years based on cluster membership indicated differences in academic progression as measured by overall GPA and engineering GPA. Here, we can add a fourth year to our longitudinal dataset of students who initially took the SUCCESS survey in the 2017-2018 academic year. The trajectory of the average cumulative overall GPA, average quarterly overall GPA, an average cumulative GPA for College of Engineering Courses (CENG), and the average quarterly GPA for CENG courses over time gives a compelling look at how NCA profiles relate to this traditional measure of academic performance. Figures 1-4 show how cluster membership relates to GPA across the quarters since the students enrolled at Cal Poly. There are thirteen quarters for which the GPA is calculated (Cal Poly is on a three-term academic year). These quarters are identified with the three terms (fall, winter, spring) and the number indicating the year at the university. Summer quarters are not included in this analysis. Note that Cluster 4 is not included here due to their low numbers at this point in the dataset.

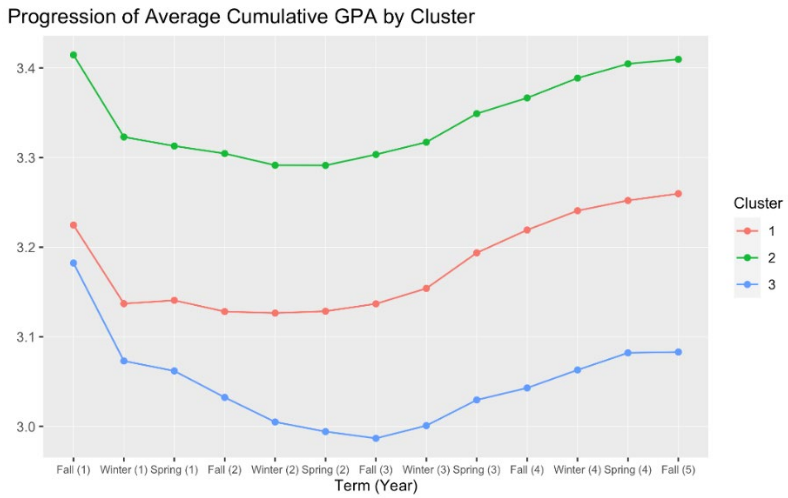

Fig. 1: Trajectory of the average cumulative GPA of members of each cluster on an expanded scale.

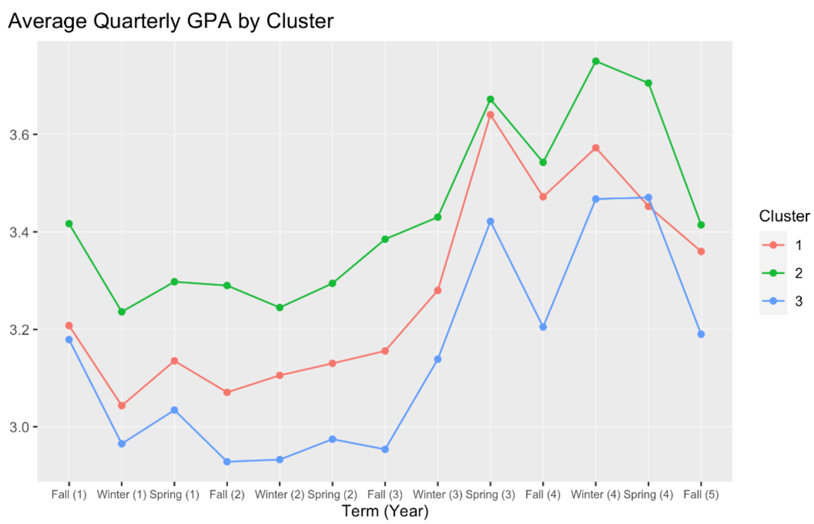

Fig. 2: Trajectory of the average quarterly GPA of members of each cluster on an expanded scale.

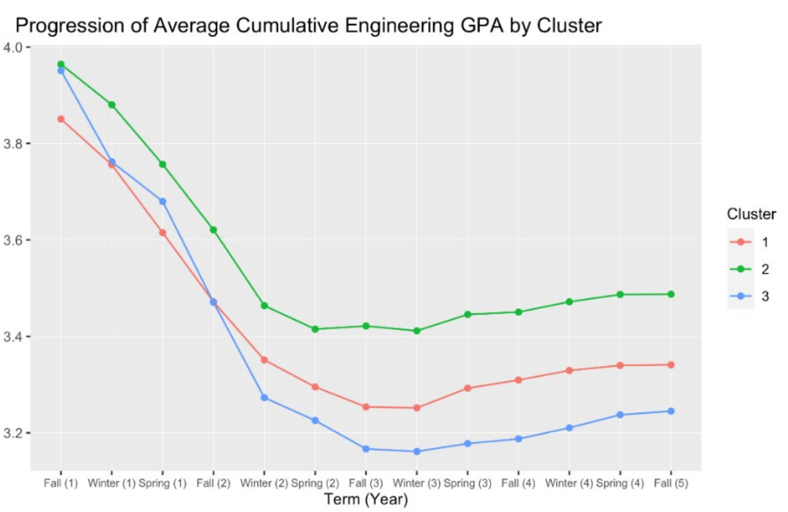

Fig. 3: Trajectory of the average cumulative engineering GPA of members of each cluster on an expanded scale.

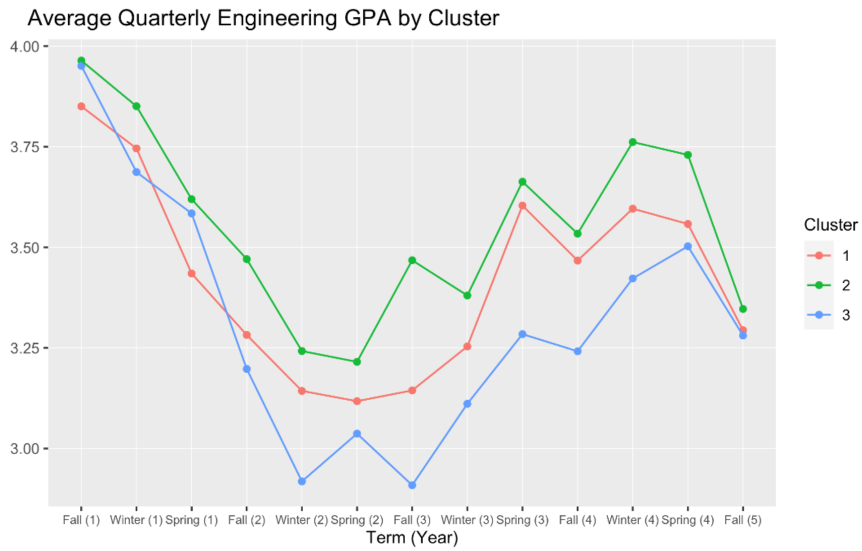

Fig. 4: Trajectory of the average quarterly engineering GPA of members of each cluster on an expanded scale.

In Figures 1 and 3, we see that, for all clusters, overall average cumulative GPA and Engineering GPAs fall as students progress through the curriculum with Cluster 3 (Unconnected and Closed Off) declining the fastest. However, around Spring (2) and Fall (3), we notice a gradual increase in GPAs up until Fall (5) with the largest jump in GPA from Winter (3) to Spring (3) (Fig. 1 and 3). Also, for the data, it should be noted that terms from Winter (3) to Spring (4) may display unusual behavior due to COVID-19 pandemic. Winter (3) concluded with virtual finals, and some classes canceling finals entirely. Furthermore, Spring (3) saw the biggest change, as many departments at Cal Poly allowed all or most classes to be taken as credit/no credit. The student could make this decision late in the quarter to maximize their GPA and this policy continued to the end of Spring (4). Because the number of units graded weights cumulative GPA, the pandemic did not affect cumulative GPA nearly as much as it did quarterly GPA.

As seen in Figures 2 and 4, within the first 4 quarters, the quarterly engineering GPA is higher than the quarterly overall GPA for all three clusters. This may be because students take introductory engineering courses during the first few terms, which could be easier than their non-major courses. Note the program is largely lockstep for the first 4 or 5 quarters, but after that, students will be taking a variety of different courses. This could explain why the average quarterly overall and engineering GPAs are more similar in the later quarters. In Figures 2 and 4, we notice that both quarterly overall and engineering GPA vary by quarter, especially during the quarters following COVID-19. Additionally, the large drop in quarterly GPAs of Fall (5) may be a result of ending the policy where students could decide later in the quarter whether a class was taken as credit/no credit.

In all cases, members of Cluster 2 (High Positive NCA Factors) have the highest average GPA, followed by Cluster 1 (Typical Cluster) and then Cluster 3 (Unconnected and Closed Off). Note that Cluster 2 includes students with strong positive NCA factors but with a fixed mindset, and Cluster 3 includes students that display more factors associated with poor academic performance. Figures 1-4 show clearly that students in clusters with high NCA factors do indeed show better academic performance. In addition, the graphs show that the difficulties students experience in engineering programs tend to increase from the first to the second year. Since the third and fourth years were impacted by COVID-19, it is unclear whether students experience more difficulty due to potentially inflated grades. Nevertheless, clusters with high NCA factors still maintained better academic performance. These results continue to suggest that improved academic performance may be possible if sets of malleable NCA factors could change through targeted interventions.

Intervention

In fall 2021, a values affirmation intervention developed at Purdue University was piloted at Cal Poly with first-year Mechanical Engineering students. The full details and results are reported elsewhere at this conference. Based on substantial prior research [10], values affirmation may help student identify as engineers, improve their sense of belonging, and subsequently increase their motivation for engineering studies. The intervention consisted of a pre-survey, followed one week later by a values affirmation exercise consisting of brief reflection and writing about one's values, followed one week later by a post-survey, and ending with a follow-on survey several weeks later to test whether any resulting impacts were sustained. Students were randomly assigned into one of three activities during the second week: the values affirmation exercise, a challenge exercise in which students reflected on the relative importance of the various Grand Challenges of Engineering, or a control in which they wrote about something they are looking forward to in the upcoming academic year. Preliminary results are reported elsewhere at this conference and a full analysis will be completed and reported in the future.

Extracurricular Activities

Extracurricular activities are another aspect of a student's academic experience that can impact their success. Activities like clubs, jobs/internships, unpaid/volunteer jobs, or competitions are all common forms of extracurricular activities participated in by Cal Poly students, prior to and during their enrollment. We are interested to know how participation in these activities might relate to individual NCA factors. During this academic year, the SUCCESS survey was slightly modified to add questions about the respondents' participation in extracurricular activities prior to enrolling at Cal Poly and during their time at Cal Poly. Respondents provided both the frequency of participation (i.e., number and type of activities) and the approximate quantity of that participation.

Data used for our analysis were collected during the 2021-2022 academic school year. First- and second-year mechanical engineering students were invited to participate in the study via the Qualtrics surveying platform. To avoid the possibility of students randomly selecting answers, a validation question was included in the survey which pointed participants to choose a specific answer. Our data was then filtered to only include responses that answered the validation question correctly. One hundred thirty-nine first-year students completed the survey; ninety-four of the responses were valid. Ninety-nine second-year students completed the survey; sixty-three of the responses were valid.

Correlation tests were conducted to explore the role of extracurricular activities in student success for the following three non-cognitive factors: engineering identity, sense of belonging, and motivation. Engineering identity has three subfields: recognition, interest, and performance/competence. Motivation has five subfields: expectancy, connectedness, instrumentality, value, and perceptions of the future. A Pearson correlation coefficient was formulated for each non-cognitive factor, and its corresponding p-value was tested at the 0.05 significance level.

In considering first-year students, the frequency of extracurricular activities (i.e., the number of instances of clubs or activities) students have prior to college was tested for its correlation with the three non-cognitive factors. Since first-year students may not have had the time to explore/participate in campus clubs or activities fully, only the data prior to college were tested. For second-year students, the frequency of extracurricular activities was tested for their correlation with the three non-cognitive factors, but in this case, only activities during their time at college were examined. Table III shows the p-values from the Pearson correlation coefficient tests.

Table II: Extracurricular activity frequency and noncognitive factor correlation P-value

	First-Year Students (n=94)	Second-Year Students (n=63)
Engineering Identity: Recognition	0.2535	0.1668
Engineering Identity: Interest	0.5317	0.0651
Engineering Identity: Performance/Competence	0.8313	0.1773
Belongingness	0.1087	0.0629
Motivation: Expectancy	0.7785	0.1932
Motivation: Connectedness	0.6214	0.6124
Motivation: Instrumentality	0.0651	0.9008
Motivation: Value	0.8496	0.9556
Motivation: Perceptions of Future	0.6648	0.4038

None of the NCA factors were found to be significantly correlated with the frequency of extracurricular activities, although several came close (engineering identity: interest and belongingness for second-year students, and motivation: instrumentality for first-year students).

The quantity (i.e., the amount of time involvement measured in hours) of extracurricular activities that a student has prior to college was also tested for the first-year students. Again, only data about these students' extracurricular activities prior to entering college was used. Additionally, the quantity of extracurricular activities that a student had during college was tested for second-year students. The results from the Pearson correlation coefficient are shown in Table III.

Table III: Extracurricular activity quantity and noncognitive factor correlation P-value

	First-Year Students (n=94)	Second-Year Students (n=63)
Engineering Identity: Recognition	0.6913	0.8652
Engineering Identity: Interest	0.2268	0.1944
Engineering Identity: Performance/Competence	0.8468	0.0701
Belongingness	0.0575	0.6231
Motivation: Expectancy	0.4837	0.0417*
Motivation: Connectedness	0.6625	0.5704
Motivation: Instrumentality	0.0651	0.4970
Motivation: Value	0.8496	0.2940
Motivation: Perceptions of the Future	0.6648	0.7230

* = statistically significant at the 0.05 level

A statistically significant correlation was observed between second-year students' quantity of extracurricular activity and *Motivation by Expectancy*. Therefore, we have evidence to reject the null hypothesis of the true correlation being equal to 0. A 95% confidence interval of the correlation coefficient was also computed between -0.4749 and -0.0103, suggesting a negative correlation between the total amount of time a student spent on extracurricular activities and their expectancy. *Motivation by Expectancy* is a construct measured from 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 [11]. In other work [12], we discovered that this aspect of Motivation on average decreases for a group (n=48) of Cal Poly who took the survey four consecutive years, regardless of whether they engaged in extracurricular activities or not. We posit that this decrease may be the result of the increasing difficulty in schoolwork each school year. This is further evidenced by the declining GPAs shown in Figures 1 and 3 and may be independent of the participation in extracurricular activities. That said, students who spend more time in extracurricular activities may struggle in courses due to inadequate time on task, which could lower *Motivation by Expectancy*.

Discussion and Future Work

For this year, the last year of the project, we plan on working further to answer RQ2 and RQ3. First, we are again surveying the entire population of Mechanical Engineering Students at Cal Poly. Now that classes are fully back in person, we anticipate the highest possible response rates by surveying in classrooms. With this dataset complete, we anticipate we will have a robust cohort of students who have taken the survey for four straight years. With this information we can do a deeper dive into malleable NCA factors and see both if there are significant changes and if so, when they might change for students during their time at Cal Poly. This knowledge may be useful in the design and timing of interventions targeting beneficial NCA factors.

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