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Intelligence Is Overrated: The Influence of Noncognitive and Affective Factors on Student Performance

Dr. John Chen, California Polytechnic State University, San Luis Obispo

John Chen is a professor of mechanical engineering. His interests in engineering education include conceptual learning, conceptual change, student autonomy and motivation, lifelong learning skills and behaviors, and non-cognitive factors that lead to student success.

Dr. James M. Widmann, California Polytechnic State University, San Luis Obispo

Jim Widmann is a professor and chair of the Mechanical Engineering Department at California Polytechnic State University, San Luis Obispo. He received his Ph.D. in 1994 from Stanford University and has served as a Fulbright Scholar at Kathmandu University

Dr. Brian P. Self, California Polytechnic State University, San Luis Obispo

Brian Self obtained his B.S. and M.S. degrees in Engineering Mechanics from Virginia Tech, and his Ph.D. in Bioengineering from the University of Utah. He worked in the Air Force Research Laboratories before teaching at the U.S. Air Force Academy for sev

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Abstract

When students struggle in their engineering studies, they tend to seek out means to improve their cognitive performance. Such assistance includes attending office hours for extra help, joining a study group or seeking out tutoring. Universities similarly focus on helping students through cognitive means, such as encouraging faculty to improve teaching methods, upgrading or improving technology resources or developing tutoring for specific courses. What is often not supported are students' non-cognitive competencies, which have been shown in previous studies to be related to academic performance. Such non-cognitive and affective (NCA) competencies include, for example, mindset, motivation, self-control, study strategies and environment, and stress management. Other NCA factors are less obvious than these and include meaning and purpose in life, gratitude, mindfulness, engineering identity, sense of belonging and perceptions of faculty caring. In this work-in-progress paper, we describe our ongoing work studying the impacts of a large set of NCA factors on student performance and student thriving. Our past work showed that most students can be grouped into one of four clusters, with each cluster having a similar NCA profile or set of factor scores. These cluster assignments have a strong and lasting influence on student performance as measured by the grade point average (GPA). This study builds on the previous work through a longitudinal study of a subset of this sample and finds that five NCA factors change significantly over time, with these changes occurring between the students' first and second years of study. Unfortunately, these factors all change in the direction that prior studies have shown to lead to poorer academic performance. These adverse changes notwithstanding, these students' GPAs are still quite strong, indicating that, if universities can help students improve their NCA competencies, students can begin to experience thriving rather than surviving.

Motivation and Background

Studying engineering is hard. The subjects are difficult, the workload is heavy and the competition is intense. Making this demanding environment even more so is perhaps an unkind culture that includes a perceived "weed-out" system and expectations of lower GPAs than students in other programs [1]. It's even been described as a culture of "suffering and shared hardship," [2] where students are often expected to be struggling to overcome the workload and stresses. Given this learning environment, it's not surprising that engineering students find success, which is usually defined as excellent grades and on-schedule graduation, elusive.

We argue, however, that success is not enough. The true measure of an excellent program is having students and graduates that thrive, meaning that they are 'doing well' and 'feeling good' [3, p. 838]. Thriving students not only succeed academically, but they are also successful at managing their interpersonal, intrapersonal and behavioral competencies. They take steps to improve in the areas that bolster the 'feeling good' part of learning engineering and set themselves up for future success by making these competencies – skills, behaviors and beliefs – an integral part of who they are.

Not all academically successful students are thriving. As defined in psychological research, thriving is a continuous process of change in which someone develops optimal functioning [4, 5]. For a college student, 'doing well' means you are in good academic standing and meeting your expectations for grades. The 'feeling good' part is not often addressed as part of the college experience but is clearly needed [6, 7, 8]. Feeling good means, for example, having the knowledge and skills to manage stress and anxiety (an intrapersonal competency), having a sense of belonging and engineering identity (an interpersonal competency), and having good study strategies (a behavioral competency). Many such competencies – which impact both negative (e.g., stress and anxiety) and positive (e.g., gratitude, motivation) functioning – can be learned and are an integral part of thriving. There is also evidence that thriving competencies present during the undergraduate years carry over to one's post-graduation career [9].

Previous Findings

Since 2016 our team has collaborated on a study premised on the importance of NCA factors for the success of engineering and computing students. The research team developed a survey instrument with evidence for reliability and validity to measure 28 factors derived from 14 constructs. The constructs and the factors derived from them [10, 11] are shown in Table I. The instrument, called the SUCCESS (Studying Underlying Characteristics of Computing and Engineering Student Success) survey, has been given to 5,300 U.S. undergraduate engineering and computing students at 20 institutions. The survey development is detailed in Ref [12].

Table I: SUCCESS survey constructs and factors.

Construct	Factors	No. of items in survey
Personality (Big 5)	agreeableness conscientiousness extraversion openness neuroticism	15
Meaning & purpose	meaning & purpose	3
Future time perspective	perceptions of future value instrumentality connectedness expectancy	18
Growth/fixed mindset	mindset	8
Grit	persistence	8
Self-control	impulsivity	9
Gratitude	gratitude	4
Mindfulness	mindfulness	4
Perceptions of faculty caring	empathetic understanding social support	13
Engineering identity	interest recognition	19
Sense of belonging	belongingness	5
Test anxiety	test anxiety	4
Time & study environment	time & study environment	8
Stress	reactions changes conflict frustrations support for stress	28

The findings to date support our original hypothesis for the importance of a constellation of NCA factors for students' academic success. For example, we found that NCA factors can account for about 26% of the variance in grade point average (GPA), which is substantial, while standardized test score (i.e., SAT or ACT) can account for only less than 10%, like prior studies found [13]. Moreover, we found that a vast majority of engineering students have an NCA profile (i.e., a collection of NCA factors scores) that falls into one of four clusters [14], and that these clusters are strongly associated with academic success as measured by the GPA [15]. In this preliminary study, we explore how NCA factors develop as students progress through their college experience. The study is based on a sub-sample from the larger study for which we had repeated measures of NCA profiles over three years beginning in 2017 when these students were first-year engineering students.

Project Framework

Our project is aligned with the framework for noncognitive factors developed by the Consortium on Chicago School Research (CCSR) [16]. The CCSR framework was developed through a detailed review of the evidence of the role of noncognitive factors that contribute to successful secondary-school performance and successful transition of high-school students to college. Although our project focuses on college undergraduates instead of high schoolers, a majority of our study participants were in their first year of studies. Furthermore, we see no logical reason why factors that are associated with college learning or success would be different between the students' year of collegiate study. Indeed, most of the noncognitive factors that the CCSR framework discusses [16] are the same as what we found to have evidence of association with academic success among college undergraduates [12, 13].

The CCSR framework consists of five categories of noncognitive factors that influence academic performance: academic mindsets, academic perseverance, learning strategies, social skills, and academic behaviors. Each of these is present in the SUCCESS survey instrument [12, 17]. Academic mindsets are one's beliefs in relation to learning and include such NCA constructs as growth or fixed mindsets and motivation. Academic perseverance refers to a student's ability to maintain focus and remain engaged with learning despite setbacks or challenges. Associated constructs that we examined are grit and self-control. Learning strategies refer to skills and behaviors that a student deploys to improve cognitive performance, such as the elements we measure through time and study environment. Social skills include most interpersonal skills that improve a student's social and professional interactions, such as personality, sense of belonging, engineering identity and perceptions of faulty caring. Finally, academic behaviors describe those behaviors that are associated with being a "good student" such as regular class attendance, submitting work on time and in good form, or class participation. Academic behaviors are outcomes resulting from a student applying the competencies described by the NCA factors in the other four categories in the CCSR framework.

Our study of NCA factors goes beyond the CCSR framework. We include such global constructs as meaning and purpose in life, gratitude and mindfulness, each of which has evidence of association with undergraduate academic performance [14]. In addition, we include factors known to be detrimental to academic performance such as test anxiety and various stressors and reaction to stress. Our original version of the SUCCESS instrument included other constructs which were later eliminated through exploratory and confirmatory factor analyses to keep the survey reasonably short [10, 11].

In addition to a framework for categorizing noncognitive factors that are associated with student success, the CCSR framework also hypothesizes a model for how these factors bolster academic performance (Fig. 1). The researchers suggest that academic mindsets not only directly impact academic behaviors but also directly impact the other three categories of noncognitive factors (social skills, academic perseverance and learning strategies), which in turn shape academic behaviors. The resulting academic or "good student" behaviors then lead directly to high academic performance while facilitated by learning strategies. An additional pathway in the model posits that improved academic performance in turn feeds back to enhance a student's academic mindsets and in this way creates a loop for continuous improvement in academic performance.

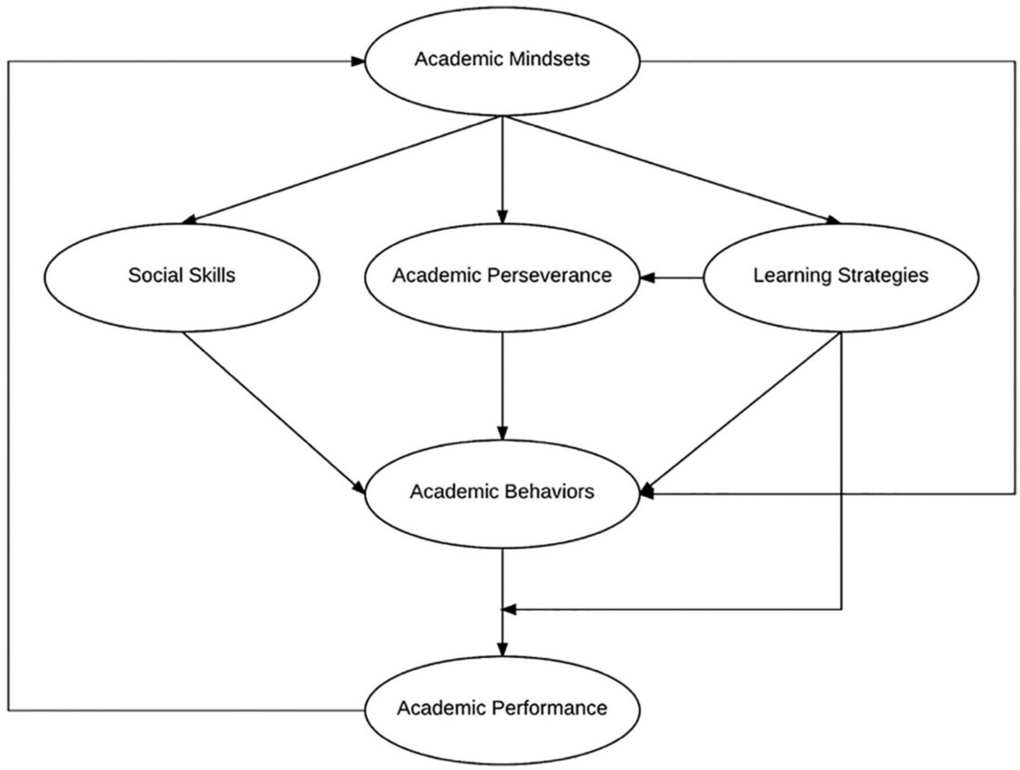

Fig. 1: The CCSR framework and model of noncognitive factors.

Results and Significance

Our original project was focused on students' academic success as measured by grades and progress toward graduation. Toward the project's end, and perhaps shaped by the myriad impacts of the pandemic, the research team's thinking evolved and we began to question whether students were thriving – i.e., doing well *and feeling good*. The answer we started to converge to was no. While the study participants were on average academically successful despite clear differences between those with different NCA profiles [14, 15], we were finding evidence that they were not "feeling good" during their development to become engineers. The evidence came from studying a group of students from one institution to examine the longitudinal changes in NCA profiles.

Forty-eight (48) survey respondents from one school, when they were all first-year engineering undergraduates, took the survey for three consecutive years, allowing us a view of how noncognitive factors evolve. To determine whether there was a difference in responses for each student for each 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 factor measured, resulting in 28 repeated measures ANOVA tests. Each ANOVA tested for differences in a student's scores for a given factor over a three-year period. To adjust for multiple tests, the Benjamini and Hochberg False Discovery Rate (FDR) method [18] was used 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, five found significant changes over time. For these five, pairwise comparisons were then conducted to identify which years were different from one another. For each factor, a paired t-test using the same FDR adjustment was conducted between each combination of years (i.e., 2018 vs. 2019, 2018 vs. 2020 and 2019 vs. 2020) to test for differences.

This sample of respondents included 33.3% females and 66.7% males. The racial and ethnic distributions are 50% White, 21% Asian or Asian-American, 6.3% Latino or Hispanic and 23% multi-race/ethnicity. These values differ somewhat from the distributions within the engineering population at this school, which is not surprising given the small sample size.

The five factors that changed significantly were: stress due to changes, reactions to stress, belongingness, engineering identity (interest), and motivation by expectancy. All five factors changed in the direction that prior research found to be negatively associated with academic success and, interestingly, all factors changed between the first and second years of college. These findings were preliminary since the sample size (n=48) was not large. To add confidence to the findings, the sample size was expanded to include participants who took the survey twice out of the three consecutive years and adding their survey data to the pool and repeating the pairwise comparisons. So, for example, participants who took the survey in their first and third years of study had their data added for the paired t-tests for that time period. The findings from the larger sample sizes (Table II) confirm the earlier findings that the five NCA factors did indeed change significantly between the first and second years of study, while they did not change between the second and third years.

Table II: Adjusted p-values from pairwise comparison of average NCA factor scores between students during different years-of-study. Significant differences ($p < 0.05$) are denoted with an asterisk.

	adjusted p-value		
Years of survey data	**2018 (1st yrs) & 2019 (2nd yrs)**	**2019 (2nd yrs) & 2020 (3rd yrs)**	**2018 (1st yrs) & 2020 (3rd yrs)**
Sample Size	73	70	106
Engineering identity (interest)	0.00123*	0.786	0.00244*
Motivation - expectancy	0.00123*	0.963	0.02369*
Stress due to changes	0.0187*	0.963	< 0.001*
Reaction to stress	0.0323*	0.786	< 0.001*
Belongingness	0.00611*	0.786	0.00920*

Conclusions

These results of a longitudinal study of students found that five of the 28 factors measured worsened significantly over time and that these changes occurred some time between the students' first and second years of study. Furthermore, it should be noted that 23 of the 28 NCA factors, many of which are a part of thriving, did not change over time during their formative experience of undergraduate studies. We emphasize that the 48 students in the study are "succeeding" academically – their average cumulative GPA was 3.38 out of 4.0. Clearly, there is a need for engineering education to not only consider students' need for curricular support but to help them go beyond success and toward thriving.

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