The Psychology of Engineering Students: Implications for Education Innovation

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Abstract. This paper aims to understand the mind of engineers in the scope of how the education system can make the field more accessible to students. Areas of particular interest include personality traits, cognition, and motivating factors of engineers, as well as their implications for education reform. The findings in literature suggest that, though they do not drastically differ from the general population in most personality factors, engineering students score significantly higher in tough-mindedness. Additionally, students are motivated by their families, and are generally both intrinsically and extrinsically motivated. Finally, given that engineers are particularly susceptible to adopting fixed mindsets, the research suggests that education reform efforts should be focused on integrating students into blended and active learning environments. Especially with the increased use of technology in STEM fields, research also implies that utilizing artificial intelligence in engineering education may offer students many benefits, though this resource must be used ethically. Ultimately, fostering a student-centered, active learning environment tailored to the unique minds of engineers can enhance both academic success and professional preparedness.

Keywords: *Engineering, STEM, Psychology, Personality, Cognition, Motivation, Education, Artificial Intelligence (AI), Education Policy, Education Reform*

Major Findings in Literature

In terms of understanding the mind of engineering students, three areas of research are particularly relevant: personality, motivation, and cognition. Accordingly, to understand how to tailor education practices to better suit engineering students, one must first understand where engineering students orient themselves in academia.

Personality Traits of Engineers

Personality traits can be defined as relatively stable, consistent, and enduring internal characteristics that can be used to explain or predicts individuals' behaviors [1]. One method of testing personality differences is through the Big Five Personality Traits test (B5T) which encompasses openness (willingness to new experiences), conscientiousness (ability to regulate impulse control), extraversion (tendency to seek social interactions), agreeableness (interaction and orientation with other people), and neuroticism (emotional instability; [2]). It has been found that there are no statistically significant differences between engineers and non-engineers (across all non-engineering majors) on any of the Big Five traits [3], [4].

Though the consensus holds that engineering students do not exhibit significant differences in all major personality dimensions, it is worth noting that there are inconsistencies in the literature when looking at specific traits. [5] found that engineering students scored significantly lower in neuroticism, contradicting [3]'s research. Additionally, [4] found that engineers scored significantly lower in conscientiousness than non-engineers. However, it is important to note that [5] compared engineering students only to social science and education majors, not the general population, suggesting that sampled students may not have been indicative of true ecologically valid findings of all non-engineering students.

It is also important to consider the assessments used in these studies. While [3] uses the B5T, which has recently been proven to be a test with both reliability and validity [2], [4] uses the Personal Style Inventory (PSI), which measures a larger quantity of personality traits. The validity of the PSI has been demonstrated by [6]; however, [7] suggest that an assessment conducted using the PSI should be followed up by another assessment type as the PSI should serve more as an approximation of personality indications. Another difference between the two studies are the participants. [4] compared engineers to non-engineers while [3] assessed undergraduate engineering students. It is possible that the difference between the findings could also be explained by the age and experience of the participants of each study. Perhaps the significant personality traits of engineers noted by [4] could have been developed during the engineers' education and work experience and the undergraduate students did not yet have the necessary experience to develop those traits on a significant level.

While there appears to be no distinguishing difference between engineering students and the average population in terms of the broad, five personality traits, there have been noticeable differences in more specific characteristics. The PSI includes more defined personality traits, one of the more notable in this case being tough-mindedness. Tough-mindedness indicates that a person makes decisions based on logic, facts, and data as opposed to emotions which is a requirement for scientific and mathematical thinking. According to [5], engineering students scored higher on tough-mindedness than other academic majors. [4] supports these findings as they found that engineers scored higher in this trait than non-engineers as well. Given the large amount of mathematics and hard sciences in both the engineering education and subsequent career, a high score in tough-mindedness would match the engineering field's priorities with facts and data. It is possible that this trait is not required for success; however, both the students and professionals exhibit this trait.

In conclusion, studies such as [3] suggest that there is no predetermined personality constellation among engineering students or professional engineers when it comes to broad personality traits such as the ones tested in the B5T. The dimensions of personality of the PSI have been linked to a work setting, and also assess the same five traits of the B5T. One of the traits assessed in the

PSI and not in the B5T, tough-mindedness, could potentially have an impact on an engineering student's and a professional engineer's success in the field.

Cognitions of Engineering Students

[8] states that a mindset is a set of beliefs, attitudes, and experiences that frame a certain way of thinking and interpreting information. A mindset in the realm of engineering has to do with the core belief that there can be solutions designed to solve problems based on the constraints of science, economics, the environment, and safety risk management. Engineers should have a mindset that allows them to understand the issues they need to address in a way that allows for the most effective solution and have empathy for the people they have designed the solution for, in the sense that it should be trouble-free to use [8]. [9] describes two differing mindsets that can be seen as having a fixed or growth mindset. A fixed mindset includes the idea that the amount of knowledge that a person possesses is fixed within their lifetime, and they cannot gain new knowledge. In this sense, knowledge means our ability to do something, such as learning math. Some people naturally struggle harder than others, while others may excel in math, and a fixed mindset believes that a person who struggles with math will continue to believe they are "not good at math." Meanwhile, a growth mindset can adapt to mistakes and understand that their intelligence is linked to their education and what they can learn to improve intellectually [10]. Continuing with the math example, a person with a growth mindset might struggle with math at first but believes they can learn and grow in the subject until they eventually improve. Throughout the duration of their first year, the engineering students slightly drifted toward a fixed mindset and away from a growth mindset. First-year engineering students were significantly more linked to a fixed mindset than a growth mindset, especially when compared to incoming business students. The engineering students who remained involved in the course curriculum for the entire year showed little drifting toward either growth or a fixed mindset, staying very stable in their original mindset [10]. These results were found through a methodology of a 27-item survey designed by Dweck, a psychologist who pioneered research on the growth versus fixed mindset, which was given to the students within the first two weeks of classes and the final two weeks of classes. This was performed to see the changes for the year and how the mindsets adapted to the course. The small amount of drifting in either direction can be accounted for by the fact that mindsets can need a long period to change effectively, and the study was only done over one year. The use of open-ended problems can positively affect growth mindset development in all categories since it allows for problems to not have a singular correct answer.

Complex thinking skills include critical thinking, problem-solving, and conflict resolution. Additionally, these skills include the ability to make connections across technical and social contexts and cross-cultural competencies [11]. These skills allow people to work with ill-defined problems that may not have specific correct solutions. [11] found that a learning style using an integrated approach, utilizing both in-person and online aspects of teaching, was found to be very beneficial for developing these complex thinking skills. This was found to be most beneficial for the engineering curriculum due to the ability to more easily reflect, contextualize, and apply what they are learning as compared to engineers in a traditional style of learning.   works and show improved results because of the hierarchical structure of knowledge in engineering [11]. Systems thinking is the ability to look at problems as part of a larger system and be able to consider how the different parts of the system interact within the system, and how they influence one another. STEM students scored slightly higher on the systems thinking skills, which required identifying both technical and contextual elements of problems, and it was noted that this is because of the prior exposure to technical solutions in their study [11]. Computational thinking is the problem-solving approach where a person breaks down a problem into smaller steps or pieces to create solutions that can be seen as computational steps or algorithms to solve each part of the problem. [12] performed a study in which they used an open-ended survey that allowed a group of both STEM and non-STEM preservice teachers to report their knowledge on computational thinking. Based on the survey responses, they found that when looking at preservice teachers, the STEM teachers saw computational thinking as the ability to logically think, coding/programming, systematic thinking, computational and analytical thinking, and methodical thinking [12]. The preservice teachers not in the STEM field were also more likely to report that they did not have any idea or very little understanding of what computational thinking was. From this, we can conclude that this difference in perception can stem from engineers having a background in computing courses in their education.

A style of learning called blended learning uses an integrated approach to teaching, which takes advantage of both in-person classroom teaching and online instructional teaching throughout a course, and it was found to help benefit STEM students more than non-STEM students and other STEM students in a lecture-based course. [13] found that 64% of the STEM students were above the mean of the non-STEM students for final course grades, even with the recognized phenomenon that engineering courses tend to be graded harder. STEM seems to benefit more from blended learning due to the higher level of feedback and networking abilities present in this learning style. Both groups also self-reported a more positive attitude about blended learning than lecture learning, although the non-STEM group reported more positively [13]. [14] found that project-based learning (PBL) in the STEM field had greater positive effects on affective mathematical engagement in terms of mathematical self-acknowledgement as compared to the non-STEM PBL students. The study included a 9-week course roughly a third of the students, 51, were taken to learning in a STEM PBL-based classroom and the other group of 96 students were taught in a traditional manner without STEM PBL. To assess the levels of affective mathematics that the students were able to reach they used the Rutgers Instrument for Mathematics Engagement (RUMESI) test. [14] found that when comparing the pre and post-tests of the learning course, the STEM PBL group was able to achieve a higher level of growth than the level of growth found in the non-STEM PBL group. When using STEM PBL the students were able to collaborate with peers to identify problems, display rigorous subject matter engagement, and demonstrate an extensive understanding of the material, all having a positive influence on the student’s affective mathematical engagement.

Motivating Factors for Engineers

Motivation can be grouped into two main categories: intrinsic motivation, where one is motivated by the prospect of personal accomplishment or satisfaction, and extrinsic motivation, where one is motivated by the prospect of recognition or reward from others. Research indicates that both male and female engineers are equally motivated by intrinsic and extrinsic factors [15], [16], [4]. This suggests that engineers desire both personal satisfaction and high regard for their accomplishments concurrently in equal amounts, among other considerations. The highest-ranking motivators overall are the interest in the subject content of the field (intrinsic factor), specifics and availability of jobs (extrinsic factor), and the opportunity for academic and personal development (intrinsic factor; [15]). Given that males and females are motivated by the same factors, yet different motivating influences, there are likely different cognitive processes that influence the overall decision to pursue this career. Research suggests that, for males, engineering is seen as a natural choice based on prior experience, whereas for females, it is a choice influenced more often by external factors, namely exposure to the field through family, friends, and instructors [15]. In understanding this important difference, the findings suggest that perhaps male are more strongly encouraged to pursue high status jobs (such as engineering) from a young age, compared to females who are motivated more so by experience.

Students in the engineering field are influenced and motivated by a variety of socio-psychological factors. The biggest source of motivation amongst both males and females to pursue engineering as a career lies in one's family [15]. It is those who are highly valued, respected, and seen as role models in one's life that influence their desire to pursue this career. This finding is especially true for female engineers, whose most important motivators are: (1) having a father in engineering, who represents a positive role model, (2) having friends and acquaintances who work in the industry, and (3) encouragement by their teachers and instructors, particularly in high school [15]. This finding suggests that females are more so motivated by social and familial connections to the field: their personal associations and positive regard for engineering because of their loved ones. For male engineers, on the other hand, the most important motivators are: (1) having an early interest in technology and engineering fields, (2) the type of high school education received (such as traditional versus polytechnic or specialized schools), and (3) personal experiences (work during breaks/holidays, experiences at home, etc.) with the engineering field [15]. Whereas females are more socially motivated, the findings suggest males incorporate their individual experiences and perceptions of the field into account when pursuing this career.

The studies described in [16] generally support that students in business-related majors are low in self-determined academic motivation: a sub-type of intrinsic motivated defined as being fully accepting of the instrumental reasons for the behaviors (academic performance) by bringing them into harmony or coherence with other aspects of their values and identity. Students in social sciences and humanities majors are high in self-determined motivation, and students in science, technology, engineering, and mathematics (STEM) and other majors are somewhere between these two major categories [16]. Additionally, this article asserts that self-determined motivation is an important explanatory factor underlying these phenomena [16]. Essentially, STEM students are moderately motivated by their own self-determination, suggesting that these students are more so a balanced mixture of intrinsically and extrinsically motivated, as compared to other college majors.

Much like engineering professionals, students in this major are motivated by similar factors. One's family, particularly parents, and parental figures, serve an important advising role for female engineering students in particular [17]. While family influence is a motivator, this does not necessarily mean students must have engineers in their family to be motivated to pursue this career themselves. In fact, around 45% of male and 37% of female students chose engineering majors who have no engineers in their families [17]. Another major motivating factor for students ties in with the benefits of engineering on society. Research suggests that both male and female students select the engineering major because of its positive impact on the community and its role in improving the way of life [17], [18]. Additionally, both male and female engineering students share similar visions to the profession in terms of the monetary value after graduation; however, more male students consider engineering to start their own business after graduation, compared to female students [17]. This suggests that men take a more entrepreneurial approach to the field than women, though both males and females value their income as a motivator.

Research offers the conclusion that there is a connection between engineering students' self-identity (the "engineering identity," by which their field of study is central to their identity) in relation to their motivational drives to achieve intended goals. The engineering identity comprises three major complementary dimensions: (1) interest in the subject, (2) perceived recognition by others, and (3) performance/competence beliefs [19]. Essentially, engineers self-identify as individuals who are personally interested in the field, have internalized beliefs that others perceive them as capable of success in the field (promoting self-actualization), and believe they can successfully understand key concepts and accomplish their work proficiently. While this tendency to self-identify with one's field of interest exists in every field, it appears as though engineers take considerable pride and identity in their field. Central to the engineering identity is the ideology that not only does the student themself feel they will succeed in this career, but that others believe they will succeed as well [19]. This postulation is supported by research: a study found that students who indicated a higher interest in engineering subjects were more likely to persist in their engineering degree pathway when controlling for major (STEM versus non-STEM), year in school, mother's level of education (a proxy for socioeconomic status), and gender, suggesting a connection between interest (the first component of the identity) and actual success in central engineering facets (math and physics) [19].

Implications for Education Reform

Based on the literature, it appears as though there is room for improvement in engineering education to better support students. One possible solution is incorporating a more active approach in engineering education. As described by [20], active learning consists of short course-related individual or small-group activities that alternate with instructor-led intervals, wherein students process and respond to new information. [21] also focuses on active learning within engineering education, reviewing the practices around the strategy. The article states that every professor can implement active learning approaches into their classes (whether in small- or large-scale integration), as the benefits are telling: increasing critical thinking, engagement, and real-time feedback on understanding for the professors. [21] emphasizes the need for institutional support for more active learning practices in universities to implement and benefit from the strategy.

[22] backs the recommendations of [21] by listing alternative teaching methods for the field of engineering. Several of these suggestions can be linked to the modern Active Learning approach. For example, [22] recommends the addition of small group activities during lectures to create active, student-centered learning. This is the same suggestion that [21] made when discussing the implementation of Active Learning activities into every class. [22] clearly sees the future of engineering education as more student-centered and like the approaches of the Active Learning strategy. However, as articles such as [21] still call upon institutional assistance to enable the inclusion of Active Learning activities into more classes, other universities likely have not yet taken this approach into full consideration and might still benefit from the addition of student-centered learning into their teaching methods.

Personality

Within the educational field, several different types of teaching methods exist, such as group work, individual presentations, or lectures, which aim to help students effectively learn the given subject and materials. The research of [23] and [24] aims to prove the correlation between certain personality traits based on the B5T model and the students' preference in teaching methods.

[23] found several significant associations between the two variables of personality traits and preferred teaching methods. Extraversion is negatively and significantly related to independent studying, likely because students who have a higher tendency to seek social interactions would prefer interactive work. Both openness and agreeableness are positively and significantly correlated among medical students with lab classes, small group work, clinical teaching, and group discussions. Neuroticism is also significantly correlated with these four teaching methods, however negatively. These findings suggest that the more open to new experiences, agreeable, and emotionally stable a student is, the more they prefer those four teaching methods. Lastly, conscientiousness was found to be positively and significantly linked to clinical teaching as the preferred method, meaning that more conscientious students with higher impulse control prefer this teaching strategy. Overall, [23] showed that there are significant correlations between the personality traits of students and their preferred teaching methods.

[24] also aims to explore the association between the preferred teaching methods of students and the personality traits of the B5T model. While the five personality traits remain the same, this study uses different variables for the teaching methods than [23]. [24] found significant, negative correlations between extraversion and guest speakers, indicating that more introverted undergraduate students prefer a guest lecturer. Extraversion was also positively linked to individual student presentations, suggesting that more extraverted students have less problems presenting to the class by themselves. Significant, negative associations were found between conscientiousness and lectures with visual overhead and watching a film (over 20 minutes long). These two teaching methods also correlate moderately with the personality trait of neuroticism, however positively. These findings suggest that students with higher neuroticism (lower emotional stability) prefer visual overheads and longer films in lectures whereas students with higher conscientiousness (higher impulse control) do not. [24] found moderate, positive correlations between the trait of openness and library research as well as technological information search. Lastly, no significant association was found between the trait of agreeableness and any of the tested teaching methods [24].

[23] and [24] both found significant links between the personality traits of students and their preferred teaching methods. However, the results of both studies have some discrepancies. Most notably, [23] found a negative correlation between extraversion and individual work whereas [24] did not find extraverted students to be linked to a preference for group work. The researcher themself describes these findings as unexpected and cites another study that also counters these results. Similarly, [23] linked the trait agreeableness to several teaching methods whilst [24] did not. Additionally, the participants themselves were different in the two studies. [23] had medical students participating and [24] used undergraduates with no specific majors. It is possible that medical students exhibit certain personality traits stronger than the average undergraduate students and thereby influence the results of the study. There is also a gender disparity between the studies. [24] had significantly more female participants (89%), which may have affected the results as the test group did not represent the wider, academic population.

If a study on the personality traits of engineering students based on the B5T model came up with significant results regarding one or some of the key traits, the preferred teaching methods of those traits could be applied to the entire engineering course to increase student satisfaction and perhaps also the academic performances of students.

Cognition

Engineers tend to have a different style of cognition when compared to their counterparts in other disciplines. If it is compared, a different style of education would benefit them more than having a style of education that is consistent across the board of disciplines. Based on previous findings, it can be concluded that within the discipline of engineering and other disciplines, there should be some framework for building a growth mindset in their students. [25] performed a study based on the relationship between a fixed mindset and academic achievement in mathematics. It was found that within a longitudinal study of tenth-grade students through twelfth grade, the students who had both a fixed mindset and a lower previous achievement in math in the tenth grade saw a decline in their mathematical achievement when transitioned into twelfth grade [25]. A large decline in math abilities due to a fixed mindset could very well be a cause for many engineers' lack of success or a potential decline in ability over time. Being able to transition their mindset from a fixed to a growth mindset would have drastic effects on their ability to maintain and improve their academic performance and overall engineering abilities. There are many ways to cultivate a growth mindset within the education of engineers, one of them being teaching the students about a growth mindset. Constructive feedback that puts more value on the effort of the student rather than the current ability of the student helps to cultivate this growth mindset [26]. Also, an emphasis on goal setting and even having self-directed/self-paced learning are very important in the development of a growth mindset within a classroom. In the future education of engineering students, a growth mindset can be seen as almost integral to the success of students, and being able to switch from a fixed mindset and cultivate a growth mindset in the classroom will benefit engineers.

The style of education is also crucial to the success of the students. There are many different styles of teaching methods, such as a blended vs a traditional classroom, where within blended there are both in-person and online aspects to the class whereas a traditional classroom is only in-person and typically lectures. It was found that a blended environment is more beneficial for the average engineering student. In the future education of engineers, it would be beneficial to have a blended learning environment to allow for the students to gain the benefits of it. These benefits can include the ability to more easily reflect, contextualize, and apply what they are learning. While at the same time being able to receive more feedback and be able to adapt to changes in the curriculum.

Motivation

Motivation plays a central role in shaping students' engagement, persistence, and identity within engineering education. Intrinsic motivation—driven by personal satisfaction and intellectual curiosity—and extrinsic motivation—driven by rewards and recognition—are both crucial in influencing students' decisions to pursue and remain in engineering fields [15], [16], [4]. Notably, research asserts that there is no difference in intrinsic or extrinsic motivation on the basis of gender, though males and females are influenced by distinct factors. Specifically, males are more often motivated by early personal experiences and interests, whereas females are more influenced by relational factors, such as encouragement from family, teachers, and social networks [15], [17]. These findings have important implications for educational policy and program development: engineering outreach efforts must go beyond presenting technical content and instead focus on fostering identity, building confidence, and creating support networks—especially for underrepresented groups. Furthermore, the concept of "engineering identity," which integrates students' interest in the field, recognition from others, and belief in their own competence, underscores the importance of creating affirming academic environments that validate students' self-perceptions [19]. Since intrinsic factors like interest in the subject and extrinsic rewards like job availability are equally valued, curriculum and advising strategies must appeal to both motivations. Failing to address these nuances could limit the field's ability to attract and retain diverse students, ultimately hindering innovation in engineering education.

Discussion

The findings mentioned suggest that there is room for improvement in how engineering students are taught, given the personalities and thinking styles of engineering students. Though the findings in literature on engineering student personalities have some inconsistencies, a distinguishable trait specific to engineering is tough-mindedness, reflecting students' reliance on logic when problem solving and making decisions. Additionally, the emphasis on problem solving plays an important role in the daily thinking and learning styles of engineers, who utilize this skill more so than any other in their studies. However, the cognitive abilities of engineering students are limited by their tendency towards fixed mindsets, which may hinder student performance over time. This plays into the levels of motivation for engineers, who generally possess a balance of intrinsic and extrinsic motivation, with factors such as family and desire to succeed being among the top motivating factors. All this considered, the research indicates that engineering students can benefit greatly from more active classroom practices, which will prompt students to be more engaged and adopt a more growth-oriented mindset in their studies. Given the increased reliance on technology in education, the use of artificial intelligence in engineering education also presents the possibility to make this field more inclusive, given that AI offers students a more personalized and direct way to interact with the field.

Implications

A major implication of this research lies in the future of engineering education, specifically in terms of making this field more equitable and accessible to students. It is known that all students have their individual strengths and weaknesses, and the same is true for engineering students. Despite sharing the common interest in the subject, some students excel in mathematics and science, while others may be more inclined towards problem solving and writing, for example. However, as the engineering major exists today, great emphasis is put on more technical skills, particularly regarding math and science. This leads many students who otherwise have great potential in engineering to be dismayed from applying if their strengths are not in these areas. In instances such as these, there appear to be benefits of incorporating technology such as AI into engineering education.

[27] and [28] emphasize the positive aspects of including AI in education, wherein AI technology offers personalized learning experiences that can benefit a diverse range of educational needs. Among the benefits of integrating AI into education, notable proposed benefits include assisting students with learning disabilities, providing personalized feedback on assignments, virtual tutoring, and adapting assignments to a students' preferred teaching method

[28]. It should be noted that these benefits are mitigated by potential threats of academic dishonesty, plagiarism, and cheating associated with AI usage, not to mention the fact that AI technology may provide false or inaccurate results at times [28]. Despite these risks, counterbalancing technology and solutions—such as plagiarism prevention software—exist, which would allow educators to uphold academic integrity in students. All things considered, it is possible that AI can alleviate inconsistencies and variations between engineering students, allowing for greater inclusion of students in the field, however, this is only possible so long as challenges are mitigated. Accordingly, further research in this area should be conducted to determine the usefulness and practicality of employing artificial intelligence in engineering education.

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