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Assessing the grit and mindset of incoming engineering students with an emphasis on gender

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***Abstract**: Engineering programs can be very demanding, particularly in the first years where students encounter new forms of highly challenging coursework. To better prepare and support students, educators must acknowledge non-academic factors, such as the role of self-beliefs and personal attributes. Education research suggests that students are more likely to give up and disengage from their studies when they lack grit or assume a fixed mindset. Previous studies suggest that female students are generally grittier but less confident when compared to male students. This paper presents the initial work of an ongoing study to explore self-confidence and motivations to study engineering of first year engineering students experiencing a new multi-disciplinary curriculum. A dataset collected via an online survey at the start of the academic year with 102 students was analysed. Gender comparisons were undertaken to explore the association between self-confidence and motivations with grit and mindsets.*

Introduction

The world of engineering is constantly evolving, requiring engineers to be able to maintain focus on long-term complex problems, and be able deal with setbacks. To better prepare students for real-world engineering problems, higher education institutions must acknowledge academic as well as psychological demands engineering challenges. Research on the role of self-beliefs and personal attributes, that include grit and mindset, is essential to understand their potential impact on academic performance and personal achievements (Burtner, 2005; Hsieh, Sullivan, Sass, & Guerra, 2012; Shechtman, DeBarger, Dornsife, Rosier, & Yarnall, 2013). This line of research can ultimately contribute to the design of evidence-based interventions to better support students.

Engineering programs are often hard, demanding high levels of self-discipline and commitment to face and overcome a variety of academic challenges (Pierrakos, 2017), particularly in the first years where students encounter challenging new types of coursework and modes of thinking. Having ‘grit’ can help students face and overcome tough challenges. Grit has been defined as perseverance and passion for long-term goals (Duckworth, Peterson, Matthews, & Kelly, 2007). Research on grit and its relationship to persistence and retention in engineering education is relatively recent, with most of the publications in the area being in conference proceedings and reporting preliminary data (Direito, Chance, &

Manish, under review). However, studies suggest that female students are, on average, grittier than male (e.g. Bottomley, 2015; Choi & Loui, 2015).

Research in engineering has linked dropout rates with self-perception, indicating students with fixed mindsets are more likely to give up when facing new challenges (Heyman, Martyna, & Bhatia, 2002). Extensive research by Dweck (1999, 2017) has indicated students with a fixed mindset believe intelligence is an innate and fixed trait. In contrast, students with a growth mindset believe intelligence can be improved with effort and drive; this second group of students is less likely to disengage when confronted with difficult tasks.

Research on grit and mindsets is particularly relevant to understanding experiences of students considered to be non-traditional, and building knowledge in this realm is essential to supporting engineering students who have diverse needs and diverse preparatory experiences. For example, a relatively recent study has reported that grit levels were positively related to black males' grades within one predominantly white institution (e.g. Strayhorn, 2014). Studies with engineering students indicated that their beliefs about intelligence were correlated with active learning strategies (e.g. Stump, Husman, & Corby, 2014), supporting the idea that developing interventions to develop growth mindsets can provide valuable support and possibly retain students in engineering (Campbell, Craig, & Collier-Reed, 2019).

In 2014, the University College London (UCL) Faculty of Engineering Sciences implemented a multi-disciplinary review of their engineering education curriculum – the Integrated Engineering Programme – where students, from the very beginning of their degree, engage with the practical application of engineering and skills needed to undertake engineering projects effectively (Mitchell, Nyamapfene, Roach, & Tilley, 2019). In the early stages, in order to study the student experiences in navigating this programme, data were collected through focus groups and online surveys. At that time, however, no data on psychological factors were included. Starting in the academic year of 2018/19, quantitative data were collected through an online survey to provide ideas for a longitudinal study of such factors.

Method

The assessment of students' psychological factors through surveys, using psychometric instruments, and is a common practice in engineering education research (e.g. Kirn et al, 2018; Scheidt et al., 2018), as it helps to identify relationships between variables in the students' profiles that support or hinder their academic success. This paper describes the initial work of an ongoing longitudinal study to explore the expectations and motivations of engineering students and the impact of grit and mindset on their learning experiences. This study follows an explanatory mixed methods design (Borrego, Douglas, & Amelink, 2009), with two phases: The quantitative data collected via an online survey (phase 1), will be analysed and findings will be used to inform the design of new qualitative interview questions (phase 2). Data collected in the first phase of will also help identify potential interview participants.

Participants

An initial sample of 103 first-year engineering students responded to the 2018/19 survey, 32% (N=33) identified as female (F), and 67% (N=69) identified as male (M). Only one student preferred not to answer and was excluded from binary gender comparisons. The breakdown by domicile status was 25.2% United Kingdom, 21.4% European countries, and 52.4% non-European countries. Participants were primarily based in Computer Science (30.1%) or Engineering, including Chemical (20.4%), Mechanical (19.4%), and Electronic and Electrical (17.5%). More than one-third of the students identified as Asian (38.8%) and almost a quarter identified as White (23.3%). The vast majority of the students were second-generation students (79.6%), meaning that they were not first in the family studying in Higher Education.

Survey and instruments

During the first weeks of the 2018/19 academic year, incoming engineering students completed an online survey comprising statements about their self-confidence regarding a set of specific engineering skills and motivations to study engineering. Survey statements regarding self-confidence were adapted from previous surveys developed by the IEP team, where students answered the question 'How confident are you in your current skills and ability to do the following?' using a 5-point-Likert scale (1 = not at all confident; 5 = very confident). In the new survey, statements exploring motivations to study engineering were adapted from the Academic Pathways of People Learning Engineering Survey (APPLES, by Sheppard et al., 2010). The APPLES survey defined motivations according to different categories: financial (F), parental influence (PI), social good (SG), mentor influence (MI), intrinsic-psychological (IP), and intrinsic-behavioural (IB). Students indicated the extent to which each reason to study applied to them using a 5-point Likert scale (1 = not a reason; 5 = major reason). A list of possibilities was presented following the explanation, 'We are interested in knowing why you are studying engineering'.

Participants were also asked to respond to two psychometric instruments—the Short Grit Scale, and Implicit Theories of Intelligence Scale—both of which are described below.

Short Grit Scale

The Short Grit Scale (Grit-S), is an abbreviated version (Duckworth & Quinn, 2009) of a self-report instrument originally developed measure the two dimensions of grit (Duckworth, Peterson, Matthews, & Kelly, 2007). These two dimensions are: (1) *passion* or, more specifically, 'consistency of interest' and (2) *perseverance* for long-term goals, which is also known as 'perseverance of effort'. Passion is defined as the ability to hold the same interests over time, whereas perseverance is defined as the ability to work consistently towards a defined goal. The short version on the instrument comprises 8 items (4 items for each dimension, passion and perseverance) to be answered according to a 5-point Likert scale, ranging from 1 'not at all like me' to 5 'very much like me'. One overall grit score is calculated for each person by totalling the sum of the scores and then dividing it by the total number of items. A grit score of 5 is, therefore, the maximum value of the instrument and it would describe a very gritty person. On the opposite end, a grit score of 1 is the minimum value a person could rate and it would describe someone who lacks grit.

Implicit Theories of Intelligence Scale

This study also seeks to understand mindset, and thus investigates the theories of intelligence that students hold. Students' ideas about intelligence were measured using the 8-item Implicit Theories of Intelligence Scale (Dweck, 1999). Of the 8 items, 4 items correspond to growth mindset (incremental theory of intelligence) and 4 correspond to fixed mindset (entity theory). When completing this survey, participants were instructed to indicate the extent to which they agreed or disagreed with each of the statements using a 6-point Likert scale (1 'strongly agree', 2 'agree', 3 'mostly agree', 4 'mostly disagree', 5 'disagree', 6 'strongly disagree'). Participants' scores for the 'growth items' were reversed (e.g. 1 becomes a 6, 2 becomes a 5, etc.), so that strongly disagreeing with a 'fixed item' was similar to strongly agreeing with a 'growth item'. The score was then calculated by dividing the sum of individual scores by the total number of items. Using this system, scores ranging between 1 and 3 suggest the individual has a fixed mindset, whereas scores between 4 and 6 suggest growth mindset. Scores in between 3 and 4 represent an unclear positioning.

Procedure

The current research project was evaluated and approved by UCL Ethics Committee because personal data, such as students' demographics, were to be processed. Following good practices of General Data Protection Regulation (GDPR), all potential participants were given an information sheet about the project and data handling.

The dataset was analysed using SPSS 25. For reporting purposes, the level for statistical significance was set at 0.05. Appropriate non-parametric tests were selected because the distribution of most of variables under analysis (items for self-confidence, motivation to study, grit and mindsets) had not passed the tests for normality. Since they did not follow a standard normal distribution, the data were analysed using Mann-Whitney non-parametric tests to assess whether the medians of the two independent groups (female and male) differed significantly from each other. Effect sizes for Mann-Whitney tests were calculated according to Fritz, Morris and Richler (2012) and interpreted using Cohen's rule of thumb (1988) with 0.1 tagged as a small effect, 0.3 as medium, and 0.5 as large. Spearman correlation coefficients were also analysed—to identify the statistical dependence between the rankings of two variables (e.g. level of confidence in skill and level of grit).

In addition to describing the overall findings for the total sample of students, the analyses presented in this paper identify correlations between students' gender and: self-confidence in a set of engineering related skills; motivations to study engineering; grit; and mindset.

Results

Participants were asked to rate their level of confidence and ability to perform a set of 15 skills using a 5-point Likert scale (1 = not at all confident; 5 = very confident) (Table 1). As a group, female students rated themselves significantly lower with regard to "solving ill-defined real-world problems" (r=.28) and "applying technical engineering knowledge to real problems" (r=.31) than male students rated themselves.

Although the group of women also rated themselves lower in "solving technical engineering problems and performing calculations" and "working with engineers from other disciplines and supporting each other to reach project goals" than men did, these confidence differences did not reach statistical significance at the prescribed level. Likewise, no significant gender differences were found in regard to the motivations for studying engineering (Table 2). The most relevant of the motivations were intrinsic, including motivations related to social good. Nonetheless, male students were more likely to rate higher in statements concerning intrinsic motivation (e.g. "I feel good when I am doing engineering", "I think engineering is fun"), whereas female students were more likely to rate higher in statements related to the social good of engineering (e.g. "Engineering skills can be used for the good of society").

The analyses of students' scores on the psychometric instruments revealed no statistical significant gender differences, although female students were more likely to have lower levels of grit and were more likely to consider intelligence as being incremental (Table 3).

Data were then analysed to explore the relationship between students' self-confidence and motivations to study engineering with regard to both grit and mindset.

For the female group as well as the male group, moderate positive correlations were found between grit-perseverance and "working effectively within a diverse and multidisciplinary team of people" (female: r=.443, p=.010; male: r=.380, p=.001) as well as "presenting ideas to other in a clear and engaging way" (female: r=.374, p=.032; male: r=.390, p=.001). These findings suggest that students' confidence in this type of social and communication may be associated with their reported subjective ability to work persistently.

In addition to this, and just for male students, small positive correlations were found between grit-perseverance and both "applying technical engineering knowledge to real problems" (r=.239, p =.048) and "thinking and working in accordance to ethical principles" (r=.245, p=.042). Also, for male students, a small positive correlation was found between mindset and "interacting with clients to provide a technical solution that suits their needs, solves their problems and helps them reach their goals" (r=.282, p=.019).

Table 1. Differences in skills confidence by gender

Survey item	gender	M	SD	Mdn	*U*	*p*	*r*
*Solving ill-defined real-world problems	F M	2.55 3.07	0.711 0.929	2.00 3.00	1,511.0	.005	.28
Developing innovative and creative engineering ideas	F M	3.15 3.19	1.064 0.928	3.00 3.00	1,170.5	.810	.02
Working effectively within a diverse and multi-disciplinary team of people	F M	3.85 3.70	0.870 0.960	4.00 4.00	1,026.0	.397	-.08
Solving technical engineering problems and performing calculations	F M	3.24 3.55	0.902 0.993	3.00 4.00	1,321.0	.172	.14
Designing and building an effective prototype	F M	2.79 2.97	0.992 0.907	3.00 3.00	1,246.0	.419	.08
Making intelligent estimates of size, scale and quantity using engineering knowledge	F M	2.88 3.20	0.927 1.051	3.00 3.00	1,309.0	.203	.13
*Applying technical engineering knowledge to real problems	F M	2.85 3.45	0.834 0.867	3.00 3.00	1,549	.002	.31
Working in a professional real-world engineering setting	F M	2.61 2.99	0.899 1.091	3.00 3.00	1,355.0	.106	.16
Presenting ideas to others in a clear and engaging way	F M	3.30 3.38	0.918 1.214	3.00 3.00	1,192.0	.693	.04
Interacting with clients to provide a technical solution that suits their needs, solves their problem and help them reach their goals	F M	2.97 3.23	1.104 1.017	3.00 3.00	1,311.0	.199	.13
Working with engineers from other disciplines and supporting each other to reach project goals	F M	3.30 3.51	0.984 0.949	3.00 4.00	1,263.0	.349	.09
Writing technical reports	F M	2.85 2.68	1.093 0.931	3.00 3.00	994.0	.280	-.11
Developing sustainable solutions on behalf of a company or for clients	F M	2.67 2.93	0.924 0.846	3.00 3.00	1,325.0	.155	.14
Thinking and working in accordance to ethical principles	F M	3.58 3.59	0.936 1.062	4.00 4.00	1,165.5	.838	.02
Considering the social impact of engineering decisions and products	F M	3.48 3.43	0.939 0.977	4.00 4.00	1,097.0	.753	-.03

Note: Statistical significance identified with *

Table 2. Motivations to study by gender

Survey item (Category)	Gender	M	SD	Mdn	*U*	*p*	*r*
Technology pays an important role in solving society's problems (SG)	F M	3.82 4.12	0.950 0.883	4.00 4.00	1,351.0	.105	.16
Engineers make more money than most other professionals (F)	F M	2.88 2.93	1.166 1.264	3.00 3.00	1,157.5	.889	.01
My parent(s) would disapprove if I chose a major other than engineering (PI)	F M	1.39 1.61	0.899 1.114	1.00 1.00	1,237.5	.377	.09
Engineers have contributed greatly to fixing problems in the world (SG)	F M	4.00 4.00	0.791 0.840	4.00 4.00	1,143.5	.969	.00
Engineers are well paid (F)	F M	3.15 3.03	1.004 1.124	3.00 3.00	1,076.5	.645	-.05
My parent(s) want me to be an engineer (PI)	F M	1.48 1.68	0.939 1.157	1.00 1.00	1,201.5	.586	.05
An engineer degree will guarantee me a job when I graduate (F)	F M	3.12 2.84	1.053 1.244	3.00 3.00	988.0	.267	-.11
A faculty member has encouraged/inspired me to study engineering (MI)	F M	2.30 1.96	1.334 1.230	2.00 2.00	957.0	.168	-.14
A non-university affiliated mentor has encouraged and/or inspired me to study engineering (MI)	F M	1.97 2.12	1.075 1.290	2.00 2.00	1,170.5	.809	.02
A mentor has introduced me to people and opportunities in engineering (MI)	F M	1.91 1.84	1.128 1.106	1.00 1.00	1,101.5	.773	-.03
I feel good when I am doing engineering (IP)	F M	3.27 3.59	1.232 1.089	3.00 4.00	1.323.0	.165	.14
I like to build stuff (IB)	F M	3.55 3.88	1.348 1.145	4.00 4.00	1,293.5	.248	.11
I think engineering is fun (IP)	F M	3.73 4.07	1.126 1.005	4.00 4.00	1,342.5	.124	.15
Engineering skills can be used for the good of society (SG)	F M	4.36 3.99	0.742 1.022	5.00 4.00	915.5	.089	-.17
I think engineering is interesting (IP)	F M	4.12 4.29	0.992 0.909	4.00 5.00	1,253.0	.373	.09
I like to figure out how things work (IB)	F M	4.33 4.49	0.890 0.816	5.00 5.00	1.250.5	.349	.09
A mentor has supported my decision to major in engineering (MI)	F M	2.18 2.01	1.261 1.254	2.00 2.00	1.035.0	.431	-.08

When exploring students' motivations to study engineering, moderate negative correlations were found among female students between grit and "engineers make more money than most of other professionals" (r=-.484, p=.004) and "engineers are well paid" (r=-.544, p=.001), suggesting that women with lower grit levels were more likely to have financial motivations to study engineering.

For male students, positive correlations were found between the grit and three specific intrinsic psychological motivations: "I think engineering is interesting" (r=.403, p=.001), "I feel good when doing engineering" (r=.238, p=.049), and "I think engineering is fun" (r=.377, p=.001). Curiously, the reason "I think engineering is fun" has a stronger correlation with the perseverance trait (respectively, r=.381, p=.001; r=.397, p=.001) than with the passion trait (respectively, r=.241, p=.046, r=.251, p=.037). A small positive correlation was identified between grit-perseverance and the intrinsic behavioural reason “I like to figure out how things work” (r=.287, p=.017).

Table 3. Overall psychometric scores by gender

Instrument	Gender	M	SD	Mdn	U	P	r
Grit	F	3.35	0.621	3.250	1,258.0	.391	.08
	M	3.45	0.582	3.500			
Grit-passion	F	3.23	0.754	3.250	1,122.5	.908	-.01
	M	3.23	0.756	3.250			
Grit-perseverance	F	3.48	0.746	3.500	1,326.5	.176	.13
	M	3.68	0.663	3.750			
Mindset/Intelligence	F	4.02	0.720	4.000	1,066.0	.604	-.05
	M	3.87	1.190	3.875			

For female students, a moderate negative correlation was found between mindset and “my parents would disapprove if I chose a major other than engineering” (r=-.407, p=.019), suggesting that this parental influence motivation was more likely to be relevant for women with a fixed theory of intellectual ability.

On the other hand, among male students, a small negative correlation was identified between grit and the same statement, “my parents would disapprove if I chose a major other than engineering” (r=-.239, p=.048), suggesting this parental influence was more relevant for male students with lower levels of grit. In addition, for male students, a small negative correlation was found between grit-perseverance and “my parents want me to be an engineer” (r=-.255, p=.034), suggesting that those doing engineering for their parents might persevere less. Also, for the male group, a small positive correlation was evident between mindset and “a non-university affiliated mentor has encouraged and/or inspired me to study engineering (r=.293, p=.014), linking growth mindset to those with encouraging mentors.

Discussion

This study aims to expand on the assessment of student perspectives and characteristics that could influence learning approaches and success. Initial quantitative data analyses, reported here, corroborate previous findings made during assessment of first-year IEP engineering students’ self-confidence; those early findings suggested UCL’s female IEP students were more likely to feel less confidence in their technical skills (Direito, Tilley, & Mitchell, 2018). However, none of these findings are yet clear enough to generalize or make robust interpretations. Further research over time, expanded to include qualitative data collection, will help the team better understand the role psychological factors play in students’ confidence during their engineering studies, and support the assessment and refinement of learning environments in the IEP and engineering education more generally.

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