Grit in engineering education
A systematic review

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Conference Key Areas: Engineering skills, Gender and Diversity

Keywords: grit; engineering education research; systematic review

1 INTRODUCTION

With the rapid pace of technological changes, future engineers are not only expected to be 't-shaped' professionals – with a broad and deep technical set of skills – but also to be able to adapt to a continuously evolving environment in solving complex and challenging problems. The traditional approach of engineering knowledge of maths and physics is no longer appropriate to today's challenges. Thus, the ability to be passionate about engineering and a persistent problem-solver, particularly when facing setbacks, is now considered to be as important as the ability to apply maths and physics.

At the same time, there is an urgent need to attract more people to engineering degrees. A few engineering faculties in the UK – such as UCL Department of Civil, Environmental and Geomatic Engineering – have already drop maths and physics A-levels as an entry requirement, and reported an increase in the diversity of their student cohorts. One of the main challenges of engineering education providers is now how to attract students who are passionate about engineering, who are flexible and have a

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broad spectrum of knowledge and abilities. This raises the interest for non-cognitive skills and, more recently, engineering educators and researchers have been focusing on the psychological demands of engineering, and the importance of personal attributes such as grit.

1.1 Grit

Research on grit has gained momentum in the past decade. It is defined as "perseverance and passion for long-term goals" [1], and has been related to both academic and personal achievements. It was initially studied by Angela Duckworth, who found that grit was a stronger predictor of students' retention in military schools and higher positions in spelling contests than academic measures such as grade point average (GPA). The Grit Scale [1] was developed as a self-report instrument to measure the traits of passion (consistency of interest) and perseverance (perseverance of effort) for long-term goals. The original version of the scale, commonly referred as Grit-O, comprised 12-item using a 5-point Likert scale (1 'not at all like me', and 5 'very much like me'). Two years later, Duckworth and Quinn [2] developed and validated a shorter version, Grit-S, comprising 8 items. The instrument retained the 2-factor structure of the original scale and improved psychometric properties.

Grit is particularly relevant when studying the academic success of students from non-traditional backgrounds. Recent studies have reported that grit levels were positively related to Black male's grades in predominantly White institutions [3]. Other studies have found that at the beginning of their engineering studies, female students viewed themselves as more hard working and diligent, and more likely to say they had overcome setbacks to conquer a challenge than their male counterparts [4].

1.2 Grit in Engineering

The world of engineering is constantly evolving, requiring engineers to be able to adapt and keep the focus in long-term complex problems. Education and training have been focusing mainly on academic and transferable skills, but initiatives designed to address the psychological demands of engineering are rare. Being an engineering student requires a great amount of grit [5]. Engineering programs are often harder, demanding a high self-discipline and commitment towards a variety of different academic challenges.

Research studies of grit in engineering education are still scarce, but suggest that persistence and achievement in engineering are related to non-cognitive factors [6]. Thus, a systematic review is fundamental to situate the context, as well as prior and current work on grit in engineering education.

2 METHOD

This paper presents a systematic review of purposely selected publications, with the aim of providing an overview of the studies conducted on grit within the context of engineering higher education [7].

The research question that guided this review was: *'What type of studies have been conducted and what methods have been used to study grit in engineering higher education?"* Complementary questions were added to better understand the target population (academic year, engineering discipline, gender, ethnicity, and generational status), the instruments used, and the main findings: *"What populations have been studied?"*, *"What measures/instruments have been used to assess grit?"* and *"What were the main findings?"*

Three types of databases were searched for publications:

- Subject specific databases – Engineering Village
- Journal databases – Journal of Engineering Education; European Journal of Engineering Education; International Journal of Engineering Education
- Gray literature databases – Conference papers and proceedings: ASEE Peer; IEEE Xplore

Figure 1 summarizes the literature review process (concluded in March 2018, meaning that more recently published records were not captured). The word 'grit' was searched in all fields, with the exception of Engineering Village database, where the search was limited to 'grit AND education' in addition to specific vocabulary (students; engineering education; education; teaching; surveys), to filter the relevant publications out of a total of 8466 records. Following the search phase, duplicate records were removed and exclusion criteria were applied to select the final eligible records. All the records that reported studies in engineering higher education and explored 'grit' were considered eligible. A final set of 31 records were initially analysed by abstract and then by full-text, including 29 conference proceedings and 2 journal papers.

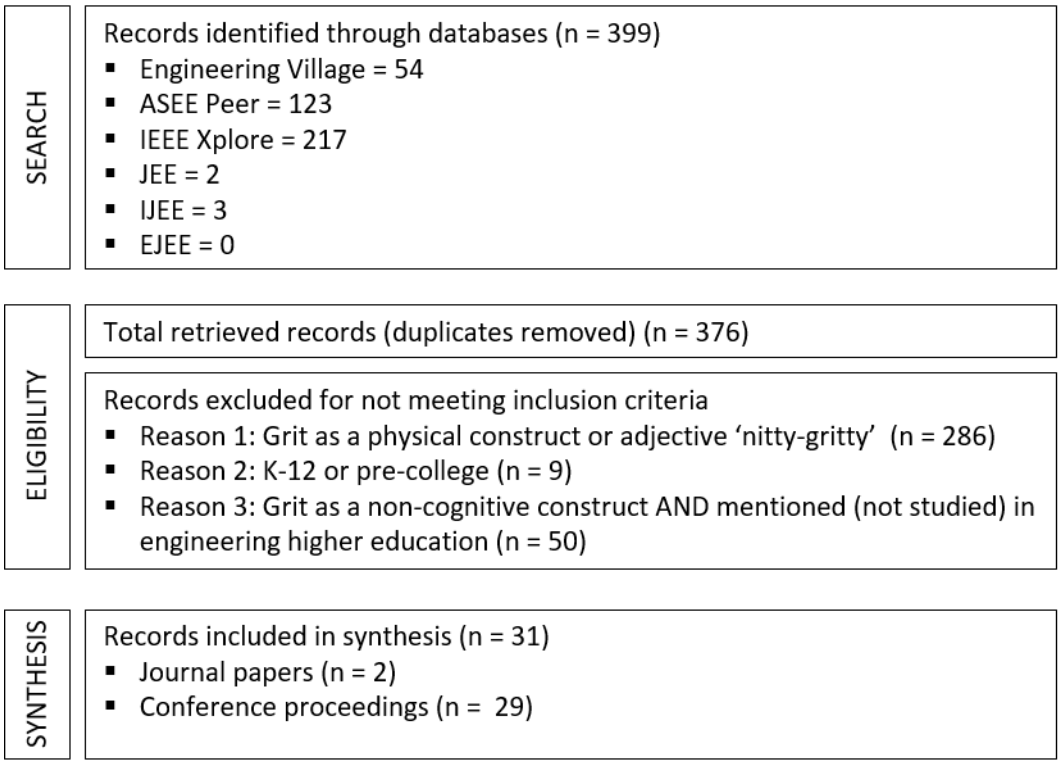

Fig. 1. Flow diagram of the literature review process

3 RESULTS

The selected 31 records were analysed by research topics and population, methods and main results. A summary of the analysis is presented in Table 1. Although not presented in the table, most of the studies have been conducted by institutions in the United States (28 out of 31), and 11 were inter-institutional collaborations.

Table 1. Systematic review of the records included in synthesis

Paper	**Research topic and population**	**Methods and instruments**	**Results**
Jaeger, B., Freeman, S., Whalen, R., & Payne, R. (2010). Successful students: Smart or tough?	Academic success. First year students. N = 370	Quantitative Longitudinal Not clear what version of Duckworth's grit scale was used	Significant gender differences in Brief and Total Grit, and Consistency of Interest) - female higher than male.
Bennett, R. M., Schleter, W., & Raman, D. R. (2012). A success enhancement program after the first test in Freshman engineering.	Assessment of programmes. First year students. N = 375	Quantitative Grit-S	Average grit scores of students who passed the class was higher, although non-significant, than the ones who did not.
Bennett, R. M., Schleter, W., Olsen, T., Guffey, S., & Li, W. (2013). Characteristics of students who do not do homework.	Academic success. First year students. N = 409 (N = 20 interviewees)	Mixed methods (survey and interviews) Grit-S	Students completing more of their homework had a higher grit than students completing less, and higher school background on physics and maths
Lerner, A.-M. (2013). Gritty students: The effect of perseverance on retention for traditional and non-traditional students.	Retention. Non-traditional students. N = 129	Quantitative. Longitudinal Grit-S	(preliminary results reported) Junior and Senior students were grittier than Freshmen.
Montoya, L., Sandekian, R., & Knight, D. (2013). Integrating Engineering for Developing Communities into Engineering Education: A Case Study.	Assessment of programmes. First year students. N = 28	Mixed methods (survey and interviews) Grit 'scenario' was introduced as research proposal not being well succeeded.	Students' grit observed by the teacher assistant. Subjective assessment of students involved in a voluntary project abroad.
Holmes, A. L. (2014). The Effects of Test-Enhanced Learning on Student Learning in an Electric Circuits Course.	Academic success. N = 108	Quantitative Grit-S	No differences on grit and self-efficacy of students with different levels of performance
Bottomley, L. (2015). Assessing the GRIT of Incoming Engineering Students.	First year students. Gender. Ethnicity. N = 475	Quantitative Longitudinal (ongoing) Grit-O	Female students viewed themselves as more hard working and diligent, and more likely to say they had overcome setbacks
Chen, J. C., Mcgaughey, K. J., Janzen, D. S., Pedrotti, J. T., & Widmann, J. M. (2015). Grit and its role in achievement among engineering students.	Academic success. N = 420	Quantitative Grit-S	Grit significantly higher in Y1 students (Y2-Y4 equivalent). Students in the highest GPA category showed significantly higher grit than all the lower GPA categories
Choi, D. S., & Loui, M. C. (2015). Grit for engineering students.	Retention. First year students.	Mixed methods (survey and interviews)	(preliminary findings)

	N = 310 (N = 26 interviewees who have earned D/F)	Grit-S	Female students were, on average, grittier than male.
Guilford, W. H., & Blazier, A. B. (2015). Integration of academic advising into a first-year engineering design course and its impact on psychological constructs.	Academic success. First year students. N = 75	Quantitative (N = 33 experimental; N = 42 control group) Grit-O	No significant differences in grit of students in different groups. Curiosity and creativity both negatively correlated with grit.
McDermott, R., Daniels, M., & Cajander, Å. (2015). Perseverance Measures and Attainment in First Year Computing Science Students.	Academic success. First year students. N = 60	Quantitative. Grit-O	Weak significant correlation between conscientiousness, grit and achievement in course
Berger, E. J., Senkpeil, R. R., Briody, E. K., & Morrison, E. F. (2016). A pedagogical borderland? Comparing student and faculty attitudes and actions about teaching and learning.	Learning and teaching. N = 317 students N = 33 staff	Quantitative Grit-S (students only)	Misalignment between students' and lecturers' learning styles. No data on students' grit.
Bracey, J., Jones, G. D., Bracey, N., & Sadeghipour, K. (2016). Chasing the Holy Grail: Pushing the Academic Persistence of Highly Motivated, Underprepared URM Students Pursuing Engineering.	Persistence. First year students. Ethnicity. N = 507	Quantitative. Grit-O	Minority students' personal motivations (self and family), related to grit, are high. 2014 = 3.68 2015 = 3.64
Bracey, J., Sadeghipour, K., Baugh, C., & Fagan, S. (2016). Chasing the Holy Grail: Successful Academic Persistence and Retention of Highly Motivated First-Year Engineering Students.	Persistence. Retention. First year students. N = 509	Mixed methods. Cross-sectional. Grit-O	Decrease in attrition of gritty students.
Choi, D. S. (2016). Engineering survivors: Students who persist in engineering through an academic setback.	Persistence. N = 29	Mixed methods (qualitative: phenomenography) Grit-O	(preliminary results, based on N = 5) 4 categories (based on attitudes toward academic setback and the consequent behaviour towards academics: Avoider; Ignorer; Boxer; Sleeper
Choi, D. S., Myers, B. A., & Loui, M. C. (2016). Grit and first-year retention in engineering.	Retention. First year students. N = 475	Quantitative. Grit-S	(preliminary results reported) Grit not a significant predictor of retention.
Desai, A. (2016). Student Profiling to improve teaching and learning: A Data Mining Approach.	Academic success. N = 60	Quantitative. 12-item instrument to assess grit (Grit-O?)	Method for clustering students according to their IQ and grit.
Groh, J. L. (2016). Gender in the workplace: Peer coaching to empower women engineering students in the classroom and as professionals	Gender. N = 12	Mixed methods (reflective journals; Pre- and –post surveys; Weekly post-class surveys)	(preliminary results reported) No specific mention to findings on grit.

Harkins, M. (2016). Engineering Boot Camp: A Broadly Based Online Summer Bridge Program for Engineering Freshmen	Retention. First year students. N 2014 cohort = 384 N 2015 cohort = 435	Quantitative. Students completed a version of Duckworth's grit scale.	Students who completed more content had an average higher GPA and higher retention rate than students who completed less.
Kirn, A., Godwin, A., Benson, L., Potvin, G., Doyle, J., Boone, H., & Verdin, D. (2016). Intersectionality of Non-normative Identities in the Cultures of Engineering	Engineering identities. N = 371	Mixed methods. Interviews. Topological data analysis. Grit measure.	Five groups differed by affective measures. No quantitative distinction based on grit measures.
Romanella, S. M., & Novoa, C. (2016). Keeping the "SPARK" alive - Investigating effective practices in the retention of female undergraduates in engineering and computer science.	Recruitment. Retention. First year students. Gender. N = 18	Mixed methods (qualitative: focus groups)	No specific data reported on grit. Students wrote application essays in response to a "grit" related prompt.
Senkpeil, R., & Berger, E. J. (2016). Impact of non-cognitive factors on first-year performance.	Performance. First year students. N = 500	Quantitative. Cross-sectional. Grit-S	Non-cognitive factors and previous academic performance increased predictability of GPA by 7%. Grit excluded due to a significant correlation with conscientiousness.
Benson, L., Potvin, G., Kirn, A., Godwin, A. F., Doyle, J., Rohde, J. A., Verdín, D., & Boone, H. (2017). Characterizing Student Identities in Engineering: Attitudinal Profiles of Engineering Majors.	First year students. Engineering identities. N = 2916	Quantitative. Multi-institution survey data. Topological data analysis Grit instrument	Grit (consistency of interest) Non-normative group levels of grit differ (higher or lower than normative)
Berger, E. J., Guruprasad, G., & Senkpeil, R. R. (2017). Characterizing the alignment in faculty and student beliefs.	Learning and teaching. N = 296 students N = 21 lecturers	Quantitative. Grit-S (students only)	No grit data reported.
Call, B. J., Goodridge, W. H., Scheaffer, M. H., & Milliken, T. R. (2017). Entrepreneurial Motivations for High-Interest Students.	Persistence. N = 11	Qualitative (grounded theory)	Grit/persistence was mentioned by participants as a required attribute for success in entrepreneurship (perceived behavioural control).
Choi, D. S., Myers, B., & Loui, M. C. (2017). Grit and Two-Year Engineering Retention.	Retention. N = 465	Quantitative Grit-S	Perseverance of effort was significant for both Y1 and Y2 retention.
Pierrakos, O. (2017). Changing the culture in a senior design course to focus on grit, mastery, orientation, belonging, and self-efficacy: building strong academic mindsets and psychological preparedness	Senior students. N = 61	Quantitative (N = 31 experimental; N = 30 control group) (pre- and post-survey) Grit-S (perseverance)	Students grittier in the experimental group: moderate effect size

Rohde, J. A., Kirn, A., & Godwin, A. (2017). Engineering Allies: The Personalities of Cisgender Engineering Students.	First year students. Gender. N = 2916 (N = 55 cisgender)	Quantitative. Measure of grit	No specific data on grit. Cis-identifying students are more likely to persist in engineering and attempt to change themselves or the world around them through the use of engineering, than non-cis-identifying students.
Sheridan, D. & Carr, M. (2017). La confluence: A study of the interplay of noncognitive and cognitive factors in determining the success of students on undergraduate engineering programmes	First year students. Academic success. N = 60	Quantitative. Duckworth's 10 item scale	First year students were grittier than Y3. For Y3, small effect between grit and achievement.
Turgut, D., Massi, L., Bacanli, S. S., & Bidoki, N. H. (2017). Multidisciplinary undergraduate research experience in the internet of things: Student outcomes, faculty perceptions, and lessons learned.	Assessment of programmes. N = 10	Quantitative (pre- and post-surveys) Not clear if Grit-S was used	No significant differences on grit were reported.
Kirn, A., & Benson, L. (2018). Engineering Students' Perceptions of Problem Solving and Their Future.	Perceptions.	Qualitative. Interpretative phenomenological analysis.	Grit was conceptualized as short-term motivation. Grit (persistence) moderated by student's perceived instrumentality of a problem-solving task. Grit as domain and task specific, instead of a wider attribute.

4 DISCUSSION AND FUTURE WORK

The reviewed publications focused on the following research topics: first year students, retention, academic success, gender, ethnicity and engineering identities. With a few exceptions, most studies implemented quantitative methodologies and used one of the versions of Duckworth's Grit scale (Grit-O or Grit-S).

As most studies were published in conference proceedings, findings were usually presented as being preliminary or as part of larger research projects, making comparisons between studies difficult. Nonetheless, the majority of studies on academic success found a positive correlation between achievement and persistence with grit. On the other hand, no clear data patterns were found in the studies that compared grit's measures of students in different academic years (freshmen, junior and senior), and in studies that explored grit as a predictor of retention.

However, findings were more consistent in studies that addressed gender differences and underrepresentation. Overall, female students were generally grittier than their male counterparts. Recent studies on gender identities, and on more broad and latent forms of diversity, are extremely valuable contributions to understanding the culture of engineering. Studies were also consistent in reporting significant positive correlations between grit and conscientiousness.

This literature review exercise suggested that the trait of perseverance alone (persistence of effort), may be a better predictor than grit. Further research on the measure of passion (consistency of interest) would be important to fully explore the importance of grit in engineering education. In addition, the results reported in the broader literature are not clear enough about the relationship between grit and creativity. Future research on these issues is important to engineering education, and might be particularly relevant to initiatives that aim to narrow the talent gap and bring more diversity into engineering.

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