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Shannon Chance
Technological University Dublin, shannon.chance@tudublin.ie

Inês Direito
University College London, London, UK

Manish Malik
University of Portsmouth, Portsmouth, UK

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The study of grit in engineering education research: a systematic literature review

Inês Direito [a], Shannon Chance [a,b] and Manish Malik [c]

[a]Centre for Engineering Education, University College London, London, UK; [b]School of Multidisciplinary Technologies, Technological University Dublin, Dublin, Ireland; [c]School of Engineering, University of Portsmouth, Portsmouth, UK

ABSTRACT

Research on the role of grit – defined as both perseverance and passion for long-term goals – on human performance has been conducted for the past decade. It has been suggested that this non-cognitive factor is a better predictor of students' retention than traditional academic measures. These findings hold relevance for engineering education research but studies on this area are still scarce. This paper provides a systematic review of the current state of research on grit and its correlates in engineering higher education research. Publications were identified using three types of databases specific to engineering education; a final set of 31 relevant records was analysed by type of population, methods, research topics and main results. Most of the reviewed studies implemented quantitative methodologies to assess grit and also used one of the two versions of Duckworth's Grit scale. Key findings are that in engineering education research, both the conceptualisation of grit and research reporting procedures have been inconsistent. Such inconsistency hinders interpretation of the impact of grit in engineering education. In response, new research avenues and best practices for reporting are proffered.

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Engineering education research; grit; systematic review

Introduction

With the rapid pace of technological changes, future engineers are expected not only to develop both broad and deep technical skills, but also the ability to adapt quickly within continuously evolving environments all the while solving complex, challenging and often ill-defined problems (e.g. Passow and Passow 2017; Winberg et al. 2018). Education and training have been focused mainly on academic and transferable skills, but initiatives designed to address the psychological demands of engineering are rare. This raises interest in understanding personal psychological dimensions, sometimes called non-cognitive factors (Duckworth and Yeager 2015; Shechtman et al. 2013).

A commonly held perception today is that studying engineering requires grit. Engineering programs are often hard, demanding a high self-discipline and commitment towards a variety of different academic challenges (Pierrakos 2017). Perhaps as a result, research on grit has gained momentum in the past decade, with engineering educators and researchers placing attention on psychological demands of engineering and the importance of personal attributes in succeeding as an engineer (e.g. Beaton et al. 2014; Burtner 2005; Hsieh et al. 2012). Grit has been defined as the

CONTACT Inês Direito i.direito@ucl.ac.uk

combination of perseverance and passion for long-term goals (Duckworth et al. 2007), and has been found to relate to both academic and personal achievements.

Although the topic of grit has received attention across education research generally, ranging from primary (e.g. Oriol et al. 2017) to tertiary/higher education, research studies of grit in the specific domain of engineering education are scarce. Those in existence suggest persistence and achievement in engineering are related to non-cognitive factors (Besterfield-Sacre et al. 2001; Burtner 2005).

Moreover, lack of diversity in engineering is a chronic problem (e.g. Chubin, May, and Babco 2005), and grit seems to be particularly relevant when studying the academic success of students who are considered to be non-traditional in their context of study. Thus, studying grit may help educators understand how to better support diverse students in engineering. Research relevant to engineering diversity includes a recent study reporting a positive association between grit and black males' grades in predominantly white institutions (Strayhorn 2014). Another study found that female students in maths and sciences secondary education were grittier than their male counterparts (Christensen and Knezek 2014).

Thus, conducting this systematic review has been fundamental to mapping how grit has been studied in engineering education to date: identifying patterns across the studies, providing an overview of previous findings, generating new findings on the basis of this synthesis and identifying directions for future research. Drawing on the definition of grit, as studied by Duckworth, this paper aims to respond to the overarching research question 'What type of studies have been conducted on grit in engineering higher education, and what were the main outcomes?' Following the description of the most commonly used grit measurement (the Grit Scale by Duckworth et al. 2007), and an overview of critical perspectives of the grit approach, subsequent sections of the paper describe the methods used to conduct this systematic literature review, present a synthesis of the reviewed publications, and finally discuss the study's limitations and implications for future research.

Grit definition and measurement

Angela Duckworth, the psychologist who researched and conceptualised this personality trait, has found grit to be a stronger predictor of, for instance, retention in military schools (Duckworth et al. 2007) and higher rankings in spelling contests (Duckworth et al. 2011), than academic measures such as grade point average (GPA). The items that compose the original Grit Scale (Duckworth et al. 2007) were designed to be face valid for adolescents and adults, and are not specific to any particular life domain (e.g. academic, work). The Grit Scale 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. *Consistency of interest* can be defined as the ability to hold the same interests over time. *Perseverance of effort* can be described as the ability to work hard and consistently towards a goal, even when experiencing setbacks. The original version of the scale, commonly referred as Grit-O, was published in 2007 and comprised 12 items using a 5-point Likert scale (1 'not at all like me', up to 5 'very much like me'). To determine the grit score of a person, the self-reported result of each item on the instrument is added together and this sum is then divided by the total number of items. A grit score of 5 is, therefore, the maximum value it is possible to achieve using the instrument and would describe a very gritty person. On the opposite end of the scale, a grit score of 1 is the minimum value one person could rate and would describe someone who lacks grit. The two sub-scales of the instrument (*consistency of interest* and *perseverance of effort*), each assessed using the same total number of items (6 items), can be analysed separately. A shorter version of the instrument, comprising 8-items (referred as Grit-S) was developed and published. The items that compose Grit-O and Grit-S are presented in Figure 1. The shorter instrument, Grit-S, retained the 2-factor structure of the original scale and improved its psychometric properties. Since the Grit-S goodness-of-fit indexes exceeded those of the Grit-O (Duckworth and Quinn 2009), the 8-item scale is seen to better represent the grit construct than the 12-item scale.

	Consistency of interest
1	*I often set a goal but later choose to pursue a different one.
2	*New ideas and projects sometimes distract me from previous ones.
3	I become interested in new pursuits every few months.
4	My interests change from year to year.
5	*I have been obsessed with a certain idea or project for a short time but later lost interest.
6	*I have difficulty maintaining my focus on projects that take more than a few months to complete.
	Perseverance of effort
7	I have achieved a goal that took years of work.
8	I have overcome setbacks to conquer an important challenge.
9	*I finish whatever I begin.
10	*Setbacks don't discourage me.
11	*I am a hard worker.
12	*I am diligent.

Items identified with (*) were included in the Short Grit Scale (Grit-S).
(Figure adapted from Duckworth & Quinn, 2009)

Figure 1. Grit scale items.

Critical perspectives of the grit approach

The construct of grit, as defined by Duckworth, has been critically questioned in two main ways: first, regarding the construct's definition and its similarity to other known constructs such as conscientiousness and, second, regarding what Stokas (2015) called its 'dark side' and implications for (in)equality in the education system.

Critiques to definition

The loudest critiques of grit involve both: (a) its multi-dimensional and thus somewhat ambiguous definition, and (b) its value as a new or unique concept. Regarding ambiguity, across education research, a high level of consensus has not emerged regarding specific aspects of the overall construct of 'grit'. Credé (2018), for instance, asserted there is lack of evidence to support the claim that grit is composed of two different factors (perseverance plus passion for long-term goals). In conducting a meta-analytic review of grit studies, Credé et al. demonstrated grit as being strongly correlated with conscientiousness, and only a very weak predictor of academic success when comparing it to other variables such as GPA and cognitive ability (Credé, Tynan, and Harms 2016). Other studies have also found a stroung correlation between grit and conscientiousness (e.g. MacCann and Roberts 2010; Meriac, Slifka, and LaBat 2015). In addition to this, Credé, Tynan, and Harms (2016) found that individual scores for perseverance predict performance much better than either consistency (passion) or overall grit (combination of perseverance and consistency), and as a result they questioned the construct validity of grit as being composed by two factors.

The term 'non-cognitive' is meant to indicate factors other than strictly cognitive ones – personality and attitude, for example (Kyllonen, Walters, and Kaufman 2005). Relatively few scholars have studied these constructs among engineering students or practitioners. Amongst the first engineering-specific research studies related to non-cognitive traits, published in the *Journal of Applied Psychology*, were the studies of engineers' personality traits produced by Goodman (1942) and later Izard (1960). These researchers aimed to differentiate engineers and non-engineers. For example, using instruments based on Murray's Theory of Personality (e.g. Sedge 1985), Izard (1960) found that engineers rated high in traits such as achievement, order, and endurance. Presaging today's definition of grit, Murray's (1938/2008) theory had defined endurance as 'the protensity of a behavioural trend. This includes "power of endurance," persistence and conative perseveration. Opposite to these are transience, impersistence and imperseveration' (148).

One of the most-studied personality tests in existence – the Big Five personality inventory, authored by Costa and McCrae – defines the personality trait 'Conscientiousness' as the sum of

facet scales labeled *Competence*, *Order*, *Dutifulness*, *Achievement Striving*, *Self-Discipline*, and *Deliberation* (Costa and McCrae 1998). Costa and McCrae found an association between: (1) Conscientiousness as they had defined it and (2) needs for Achievement and Endurance as defined by Murray (Costa and McCrae 1988). These traits run somewhat parallel to Duckworth's definition of grit as 'working strenuously toward challenges, maintaining effort and interest over years despite failure, adversity, and plateaus in progress' (Duckworth et al. 2007, 1087).

Duckworth and Eskreis-Winkler (2013, 1) recognise that 'grit clearly belongs to the Big Five Conscientiousness family, particularly overlapping with achievement motivation'. However, these same authors, along with other colleagues, also found that grit is a better predictor of educational attainment and retention in the workplace compared to conscientiousness (Eskreis-Winkler et al. 2014).

Critiques to approach

Another major critique is the notion that a 'grit narrative', focused on individual effort and individual achievement, is detrimental to diversity and inclusion as it helps to perpetuate inequalities embedded in the education system that are out of the control of individuals (Golden 2017; Stokas 2015). Stokas (2015, 515) noted the danger of cultural conceptions of grit that entail 'the belief that social hardship, such as poverty and inequality, are overcome through heroic individual effort rather than through an ecosystem of supportive environments and policies' that provides resources essential to success. This implies there's currently too much focus on the individual and not enough on the situations that influence the individual and facilitate the individual's ability to persist and be passionate or gritty.

Considering non-cognitive factors more broadly, Turiel, Chung, and Carr (2016) note that a significant proportion of research is still focused on a 'one-dimensional approach of assessing more and less or better and worse possession of a trait by individuals' (6). The authors argue that psychological research needs to focus on understanding how individuals think and behave in specific contexts.

In response to such concerns, new models have been developed to improve the measurement of grit in non-western cultural contexts. One example is the Triarchic Model of Grit Scale (Datu, Yuen, and Chen 2017, 2018); it includes a third dimension of *adaptability to situations* that refers to 'an individual's ability to adjust effectively to changing circumstances in life' (Datu, Yuen, and Chen 2017, 199).

Methods

Using methodological recommendations for conducting a systematic literature review in engineering education developed by Borrego, Foster, and Froyd (2014), this paper presents an overview of the publications that had, as of March 2018, reported empirical research on grit among higher education students of engineering. Following the Borrego et al. process, the research team first defined the research question and criteria for selecting relevant studies, including both inclusion and exclusion criteria. Second, they selected the most relevant databases that publish research on engineering education to identify and sort potential articles for reviewing. Thirdly, after assessing the relevance of each study, they selected a final set of sources and described them according to the research question. These studies were categorised and summarised by type of publication, research topics, population or sample, and methods. Finally, the team synthesised the reviewed publications – exploring the similarities and differences of the results from different studies, and reflecting upon the contributions and limitations of each to the larger study of grit in engineering education.

Research question and selection criteria

The overarching research question that guided this review was: *What type of studies have been conducted on grit in engineering higher education, and what were the main outcomes?* Complementary questions were added to better understand: the target population (such as academic year, gender, and ethnicity); the methodological approach; and the instruments used.

To be included in this systematic review, papers were selected that both: (a) reported studies in engineering higher education and (b) explored 'grit' as non-cognitive construct.

To determine what papers were not eligible, three specific exclusion criteria were defined, regarding scope, sample, and depth. Papers were excluded if they had: (1) inappropriate scope, meaning the term 'grit' was explored as a physical construct (a synonym of sand or gravel) or used in the expression 'nitty-gritty' (an expression used to define the specific practical details of a problem); (2) non-relevant sample, meaning the studies reported in the records were with primary and secondary school (i.e. K-12) populations rather than the target for this study which involves higher education; or (3) inadequate depth, meaning records that just mentioned 'grit' as a non-cognitive construct (inclusion criteria) without conducting or reporting any study.

Selection of databases and search

Three types of databases were searched for publications in Engineering Education Research (Table 1). The team started with the comprehensive and subject-specific database *Engineering Village* since the intended focus was specifically on engineering students and not a wider population. Then, upon finding few publications of relevance to the question, the review progressed to using journal databases and, finally, databases of 'grey literature' listing conference papers and proceedings. As little engineering-related grit research had been reported via journals, this last step of searching for conference papers was necessary to uncover as much of the work as possible that had been done in this specific sub-field/domain.

The word 'grit' was initially searched in all fields of the databases, retrieving a total of 8644 records. Analysing this large group of records, it was evident that most of the researchers used the term 'grit' as a physical construct (referring to stone or sand, particularly prevalent in civil engineering studies). In order to filter the publications for relevance, the search was then limited to 'grit AND education', yielding retrieval of 399 records. Following the search phase, duplicate records were removed manually, and exclusion criteria were applied to select eligible records. A final set – 31 records in all – was analysed first by abstract and then by full text. Figure 2 summarises the literature review process, which was finalised in March 2018; it illustrates where and how many articles were included and excluded at each stage of the process.

An initial search using Engineering Village yielded 16 eligible records. ASEE Peer yielded 21 eligible records, although 8 of these were duplicates from Engineering Village. Finally, all the 5 eligible records retrieved in IEEE were duplicates. Of the resulting 31 publications deemed relevant, 29 appeared in conference proceedings (16 from *Engineering Village*, and 13 from *ASEE Peer*) and 2 in journals (one published in JEE and one published in IJEE). The set of 31 was then analysed by type of population, methods, research topics and main results.

Description of the selected publications

The research team aimed to produce well-synthesised analyses in narrative form, to provide a comprehensive picture of grit-related findings that has emerged in engineering education research literature, and to help researchers working this realm hone their approaches in ways that help the

Table 1. Searched databases.

Type	Database name
Subject-specific database	Engineering Village
Journal databases	Journal of Engineering Education
	European Journal of Engineering Education
	International Journal of Engineering Education
Grey literature databases	ASEE Peer
	IEEE Xplore

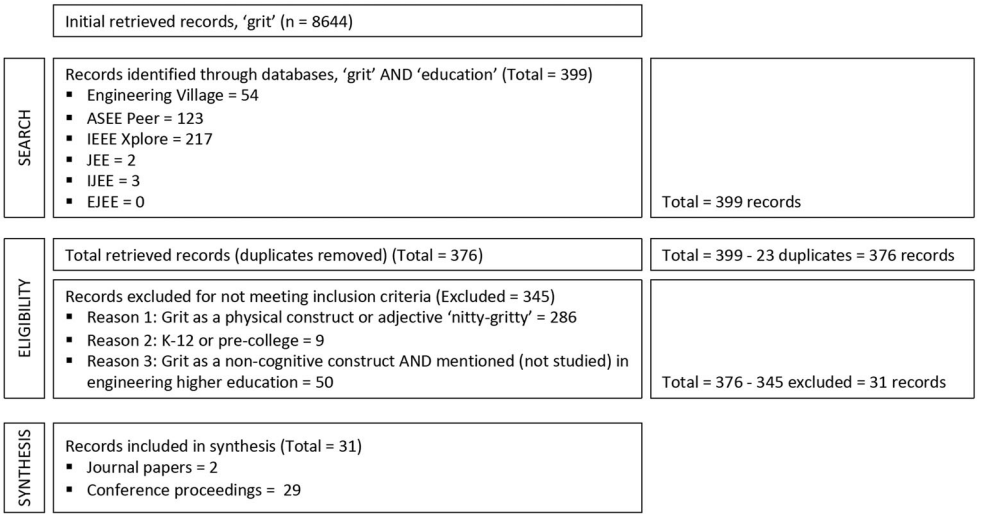

Figure 2. Flow diagram of the literature review process.

engineering education community achieve increasingly valuable findings related to the role of this construct on engineering students' performance. To achieve this, the team first created tables. According to Petticrew and Roberts (2006), tabulating the included studies is an important summary measure when organising the evidence, and it should be the first step towards a narrative synthesis. To aid in organising, comparing, and crosschecking data, Table 2 was prepared, to include a description of each selected paper based on its type of publication, research topics, population studied, and methods. Table 3 was created to provide, in narrative form, a summary of the findings of each individual study. In Table 2, the papers are presented by alphabetical listing of first author, and each one was assigned a number which is used to reference it in Table 3.

Although not presented in Table 2, most of the studies have been conducted by institutions in the United States ($n = 28$). In fact, of the 28 US papers, 13 acknowledged financial support from the US National Science Foundation (NSF). As 12 of these were conference proceedings and reflected work-in-progress, further data/analysis may be reported elsewhere in the future.

Also, of the 31 papers reviewed, 11 seemed to be the result of inter-institutional collaborations, as they were authored by more than one institution. This pattern likely results from NSF evaluation criteria in the US that favour proposals with involvement of multiple institutions.

Type of publication

Most of the papers reviewed in this systematic analysis were published in conference proceedings ($n = 29$), with the majority being presented at annual conferences of the American Society for Engineering Education (ASEE) ($n = 22$). Four papers were presented at IEEE Frontiers in Education conferences; one in the annual conference of the European Society for Engineering Education (SEFI); one in the conference on Innovation and Technology in Computer Science Education (ITiCSE); and one in International Conference on Data Science and Engineering (ICDSE).

Of the two journal papers, one was published in the *Journal of Engineering Education* (JEE), and one in the *International Journal of Engineering Education* (IJEE), in 2018 and 2017, respectively, supporting the idea that the study of grit in engineering education is in its early stages.

Table 2. Mapping of the records included in the synthesis, by type of publication, research topics, studied population, and methods.

#	Paper citation	Publication type	Research topic	Population	Context	Methods to assess grit
#1	Bennett, Schleter, and Raman (2012). A Success Enhancement Program after the First Test in Freshman Engineering.	ASEE conference	Academic success; Programme assessment	Y1	The paper reported the Success Enhancement Program (SEP), a type of grade recovery program, introducing engineering topics and basic physics concepts, designed to help students in the transition to university.	Quantitative (questionnaire)
#2	Bennett et al. (2013). Characteristics of Students Who Do Not Do Homework.	ASEE conference	Academic success	Y1	Expansion of paper #1. The main goal of the study was to identify the characteristics of students who do not do homework and develop intervention techniques accordingly.	Quantitative (questionnaire)
#3	Benson et al. (2017). Characterising Student Identities in Engineering: Attitudinal Profiles of Engineering Majors.	ASEE conference	Engineering identity	Y1	The paper presented the first phase of a project addressing how students who hold non-normative identities position themselves, grow through their education, and navigate cultures of engineering they experience in university. In this paper, grit (*consistency of interest*) was studied as being one of the most relevant attitudinal constructs (other constructs were motivation, engineering and physics identities, personality).	Quantitative (questionnaire)
#4	Berger et al. (2016). A Pedagogical Borderland? Comparing Student and Faculty Attitudes and Actions about Teaching and Learning.	ASEE conference	Learning and teaching	Students and staff	The study aimed to explore differences in attitudes and actions between students and teaching staff, and the impact of these differences on academic outcomes.	Quantitative (questionnaire)
#5	Berger, Guruprasad, and Senkpeil (2017). Characterising the Alignment in Faculty and Student Beliefs.	ASEE conference	Learning and teaching	Students and staff	Related to paper #4. The study presented in the paper is part of a broader study of faculty and student attitudes about teaching and learning, and the influence of departmental culture.	Quantitative (questionnaire)
#6	Bottomley (2015). Assessing the GRIT of Incoming Engineering Students.	ASEE conference	Persistence and retention; Gender; Ethnicity.	Y1	At the beginning of the academic year, all first year engineering students were invited to participate in a longitudinal study designed to track their semester by semester performance and persistence to graduation. After the end of the semester, grit scores were correlated with gender, ethnicity, and semester grade point average (GPA). The study aimed to examine whether grit is more, less or additionally predictive of student success.	Quantitative (questionnaire)

(*Continued*)

Table 2. Continued.

#	Paper citation	Publication type	Research topic	Population	Context	Methods to assess grit
#7	Bracey et al. (2016). Chasing the Holy Grail: Pushing the Academic Persistence of Highly Motivated, Underprepared URM Students Pursuing Engineering.	ASEE conference	Persistence and retention; Ethnicity	Y1	The paper examined motivation to persist amongst African American and Hispanic/ Latino undergraduate engineering students who lacked mathematical background. Psychological factors including grit, self-determination and social cognitive career theories were used to explore different mediators of academic achievement (e.g. self-efficacy).	Quantitative (questionnaire)
#8	Bracey et al. (2016). Chasing the Holy Grail: Successful Academic Persistence and Retention of Highly Motivated First-Year Engineering Students.	ASEE conference	Persistence and retention	Y1	Related to paper #7. The study presented in the paper examines the impact of an Introduction to Engineering course, designed to support mathematics learning, in student outcomes and retention.	Quantitative (questionnaire)
#9	Call et al. (2017). Entrepreneurial Motivations for High-interest Students.	ASEE conference	Persistence and retention; Entrepreneurial attitude.	Y3	This paper explored the backgrounds and motivations of engineering students who exhibited high entrepreneurial interest. Students with high interest were invited to participate in interviews to further explore their motivations.	Qualitative (interviews; grounded theory)
#10	Chen et al. (2015). Grit and Its Role in Achievement among Engineering Students.	ASEE conference	Academic success	Y1, Y2, Y3, Y4	The paper reported work-in-progress investigating the relationship between grit (and other psychological traits such as self-esteem, self-efficacy and growth mindset) and GPA among engineering students.	Quantitative (questionnaire)
#11	Choi and Loui (2015). Grit for Engineering Students.	IEEE FIE conference	Persistence and retention	Y1	The study explored the role of grit in the retention of first year engineering students.	Mixed methods: Quantitative (questionnaire); Qualitative (semi-structured interview, phenomenography)
#12	Choi (2016). Engineering Survivors: Students Who Persist in Engineering through an Academic Setback.	ASEE conference	Persistence and retention	Y1, Y2, Y3, Y4, Y5	Related to paper #11. This study explored the grit of undergraduate students who have faced an academic setback (earning a D or a F in a mandatory course) but continued to persist in their engineering degrees.	Mixed methods: Qualitative (interviews, phenomenography); Quantitative (questionnaire)
#13	Choi, Myers, and Loui (2016). Grit and First-year Retention in Engineering.	IEEE FIE conference	Persistence and retention	Y1	The study explored the role of grit in the retention of first year engineering students, combining data from paper #12 (2014 cohort) and #13 (2015 cohort).	Quantitative (questionnaire)
#14	Choi, Myers, and Loui (2017). Grit and Two-Year Engineering Retention.	IEEE FIE conference	Persistence and retention	Y2	The study explored the role of grit in the retention of second year engineering students (comparison of data presented in paper #13).	Quantitative (questionnaire)

#15	Desai, Shah, and Dhodi (2016). Student Profiling to Improve Teaching and Learning: A Data Mining Approach.	ICDSE conference	Academic success	Y3	The study used data mining methodologies to classify students into clusters by using different parameters–student test scores, aptitude, and grit–in order to adapt teaching to different students and support their academic success.	Quantitative (questionnaire, cluster analysis)
#16	Groh (2016). Gender in the Workplace: Peer Coaching to Empower Women Engineering Students in the Classroom and as Professionals.	ASEE conference	Gender	Y3, Y4, female	This study assessed a peer-coaching programme focusing on female engineering students.	Qualitative (journal entries)
#17	Guilford, Blazier, and Becker (2015). Integration of Academic Advising into a First-year Engineering Design Course and Its Impact on Psychological Constructs.	ASEE conference	Academic success	Y1	This study made quantitative pre- and post-comparisons of psychological constructs – curiosity, perseverance (grit), creativity, engineering design self-efficacy, creative design – in response to an instructional intervention (called 'intrusive advising'). Experimental (advising) and control (no advising) groups were compared.	Quantitative (questionnaire)
#18	Harkins (2016). Engineering Boot Camp: A Broadly Based Online Summer Bridge Program for Engineering Freshmen.	ASEE conference	Persistence and retention; Academic success	Y1	Reported the development of an online boot camp (or summer bridge program) to help students improve perseverance, maths readiness, and spatial visualisation. The boot camp included a module 'Cultivating Perseverance' discussing grit.	Quantitative (questionnaire)
#19	Holmes (2014). The Effects of Test-Enhanced Learning on Student Learning in an Electric Circuits Course.	IEEE FIE conference	Academic success	Y2 Electrical and Computer but also Y3 and Y4 in other engineering majors	Reported two experiments (1 and 2) about online quizzes as replacement for homework in Electrical and Computer Engineering. Students' performance on the quizzes was correlated with performance on course exams, conceptual understanding of the material and problem solving ability. Grit was explored in Experiment 2, with the goal to replicate findings of Experiment 1 and determine if grit could be used to explain different performance levels between students.	Quantitative (questionnaire)
#20	Jaeger et al. (2010). Successful Students: Smart or Tough?	ASEE conference	Academic success; Gender	Y1	Reported initial work of a longitudinal study to measure grit of first-year engineering students with the hypothesis that students can be better set up for success if they have more grit.	Quantitative (questionnaire)

(*Continued*)

Table 2. Continued.

#	Paper citation	Publication type	Research topic	Population	Context	Methods to assess grit
#21	Kirn et al. (2016). Intersectionality of Non-normative Identities in the Cultures of Engineering.	ASEE conference	Engineering identity	Y1	Studied how diverse students identify with engineering and navigate the culture of engineering. The paper focussed on the first phase of a larger project, reporting pilot survey data on student's identities, motivation, and psychological traits.	Quantitative (questionnaire, topological data analysis to create normative and non-normative attitudinal profiles of respondents)
#22	Kirn and Benson (2018). Engineering Students' Perceptions of Problem Solving and Their Future.	JEE	Learning and teaching	Y2, Y3	Reported how motivation and other cognitive and affective factors influence problem solving in engineering.	Qualitative (interviews, interpretative phenomenological analysis/IPA)
#23	Lerner (2013). Gritty Students: The Effect of Perseverance on Retention for Traditional and Non-traditional Students.	ASEE conference	Persistence and retention; Non-traditional students	Y1, Y3, Y4	Explored the characteristics that contribute to successful retention in an engineering program, amongst non-traditional and transfer students. Reported data collected at the start of a longitudinal study to measure grit in students enrolled in a 2-year institution (community college) that is feeder program for a 4-year institution.	Quantitative (questionnaire)
#24	McDermott, Daniels, and Cajander (2015). Perseverance Measures and Attainment in First Year Computing Science Students.	ITiCSE conference	Academic success	Y1	In this study, grit of students was correlated with data from the Big-5 personality questionnaire as well as students' programming scores.	Quantitative (questionnaire)
#25	Montoya, Sandekian, and Knight (2013). Integrating Engineering for Developing Communities into Engineering Education: A Case Study.	ASEE conference	Academic success; Programme assessment	Y1	This case study investigated a design course intended to develop and reinforce grit in students by challenging them to submit a research proposal. A grit scenario was introduced to the students in the class; it involved a research proposal that did not succeed at first but was later resubmitted and funded. Assessment of the student experience while in the classroom and during a follow-up trip.	Qualitative (interviews with students who travelled to Peru, observation)
#26	Pierrakos (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.	IJEE	Academic success	Y4	Reported programme developed to support students' psychological preparedness in an engineering course, designed as a pre-test and post-test control group design. The pre-test and post-test were exactly the same and were respectively administered a few days prior to the start of the semester and during the last week of the semester.	Quantitative (pre- and post-questionnaire)

#27	Rohde, Kirn, and Godwin (2017). Engineering Allies: The Personalities of Cisgender Engineering Students.	ASEE conference	Gender	Y1	Part of a larger cross-institutional study (n = 2916), this paper examined students STEM identities, motivation, grit and personality. It focussed on 55 students who identified as being cisgender.	Quantitative (questionnaire)
#28	Romanella and Novoa (2016). Keeping the 'SPARK' alive - Investigating Effective Practices in the Retention of Female Undergraduates in Engineering and Computer Science.	ASEE conference	Persistence and retention; Gender	Y1, female	Study of self-efficacy and confidence as predictive of persistence for female students in Engineering and Computer Science. The project was targeted to support the college experience, degree attainment, and career aspirations of talented and financially deprived female students.	Mixed methods. Quantitative (questionnaire); Qualitative (essays with 'grit' related prompt)
#29	Senkpeil and Berger (2016). Impact of Non-cognitive Factors on First-year Performance.	ASEE conference	Academic success	Y1, Y2, Y3, Y4	Study of non-cognitive factors and their impact on student academic outcomes.	Quantitative (questionnaire)
#30	Sheridan and Carr (2017). La Confluence: A Study of the Interplay of Noncognitive and Cognitive Factors in Determining the Success of Students on Undergraduate Engineering Programmes.	SEFI conference	Academic success	Y1 and Y3	This study investigated how mindsets and grit correlate with academic success.	Quantitative (questionnaire)
#31	Turgut et al. (2017). Multidisciplinary Undergraduate Research Experience in the Internet of Things: Student Outcomes, Faculty Perceptions, and Lessons Learned.	ASEE conference	Programme assessment	Y2, Y3 and Y4	This paper reports the evaluation of the Research Experiences for Undergraduates (REU) programme on Internet of Things, delivered during summer break. It reports the analysis of the first cohort of 10 students, comparing pre- and post-survey data comprising constructs such as grit, self-efficacy, research skills and knowledge, scientific identity.	Quantitative (pre- and post-questionnaire)

Table 3. Grit instruments, sample size, grit average/results, and main findings.

# Paper	Grit instrument	Sample size, *n*=	Grit average (mean, and standard deviation where provided)	Grit (other aspects)	Findings (in narrative form)
#1	Grit-S	375	3.54		Average grit score for students who passed the class was higher than the average for students who did not pass, however, the difference was non-significant.
#2	Grit-S	409	3.54 3.57 for those doing >80% homework 3.47 for those doing <80% homework		Students completing more of their homework had a significantly higher grit than students completing less, but they also had higher high school attainment on physics and maths. The correlation between grit and homework average was non-significant ($r = 0.060$).
#3	Grit *consistency of interest*. No version specified.	2916	3.4		(Preliminary findings reported). Grit was measured as *consistency of interest*. It was found that, of the seven non-normative groups identified through topological data analysis, the *consistency of interest* of group 3 was lower, and of group 4 was higher, than the normative group (differences statistically significant). No further data on the different non-normative groups was provided.
#4	Grit-S	317		Grit-S assessed in students only.	No data was provided regarding students' grit. However, a misalignment was identified between the learning styles (assessed with the 44-item Felder-Soloman Index of Learning Styles) of students and lecturers. On average, students were significantly more active and sensing learners than lecturers.
#5	Grit-S	296		Grit-S assessed in students only.	Although data was collected from students, this paper did not report it.
#6	Grit-O (Grit-S was mentioned in the paper, but the findings are presented for 12-items – corresponding to Grit-O)	475	Grit data is presented by item		This paper presented grit results by item (12 items). Female students reported viewing themselves as more hard-working and diligent than males reported. Females were also more likely to say they had overcome setbacks. The differences in these areas were statistically significant.
#7	Grit-O	280 and 229	3.68 for 2014 cohort ($n = 280$) 3.64 for 2015 cohort ($n = 229$)		Minority students' personal motivations (self and family), related to grit, were high. However, the paper did not explain whether statistical analysis was undertaken or not to check how minority students compared to other students.

#8	Grit-O	Same as in paper #7.	Same as in paper #7.		Attempting to assess the impact of the 'Introduction to Engineering' course, the authors reported a decrease in attrition of students who entered underprepared in Maths but had high levels of grit. The study registered a 5% decrease in attrition and 25% improvement in retention for at-risk first-year students (2014 cohort), and a 10% decrease in attrition and 35% increase in retention for a similar (2015) cohort. However, no statistical tests were mentioned to ascertain if improvement levels were significant.
#9	Not Applicable (N/A)	11		Grit mentioned by students as being an important attribute.	Grit/persistence was mentioned by participants as a required attribute for success in entrepreneurship (perceived behavioural control).
#10	Grit-S	402	3.41 for Y1 ($n = 163$) 2.91 for Y2 ($n = 78$) 2.93 for Y3 ($n = 76$) 2.91 for Y4 ($n = 66$) 2.89 for those staying longer than Y4 ($n = 19$)		Grit was significantly higher in Y1 students, whereas it was equivalent for students in Y2, Y3, and Y4. Students in the highest university grade-point-average category showed significantly higher grit (and higher self-efficacy and higher self-control) than students in the lower GPA categories.
#11	Grit-S	310	3.42 for total group 3.40 for males ($n = 214$) 3.47 for females ($n = 93$)		(Preliminary findings reported.) Female students were, on average, grittier than male, although this difference was not statistically significant.
#12	Grit-O	29	Not reported	Students invited for the interview completed the 12-item grit scale and a demographic questionnaire.	(Preliminary findings reported, based on $n = 5$). Four categories - based on students' attitudes towards an academic setback and the consequent behaviour towards academics – emerged from the qualitative analysis of the interviews. The categories were: Avoider, Ignorer, Boxer, and Sleeper.
#13	Grit-S	475	Not reported		(Preliminary findings reported.) Using binary logistic regression, grit was not a significant predictor of retention.
#14	Grit-S	465	3.54 for Grit (3.88 for Persistence of effort)		*Perseverance of effort*, not grit as a sum of two sub-scales, was significant for both Y1 and Y2 retention.
#15	12-item instrument to assess grit (Grit-O?) No references to Duckworth.	60	Individual scores (for each student)		This paper presented a data mining method for clustering students according to their IQ and grit. Students from a particular class were

(*Continued*)

Table 3. Continued.

# Paper	Grit instrument	Sample size, *n*=	Grit average (mean, and standard deviation where provided)	Grit (other aspects)	Findings (in narrative form)
					clustered in three groups, based on their academic performance: below average, average, and above average. Reported data suggested that students in the below average category had lower levels of grit. However, no statistical tests were mentioned.
#16	N/A	12		Students' journal entries were analysed and data was categorised into two themes: coaching impact and coaching applications. These 2 themes were then divided in 5 sub-categories, which grit/resilience being one. Other sub-categories were: general reference to personal/professional growth; empowerment of self; empowerment of others; and specific mention of use in future career.	(Preliminary results reported). Grit/resilience was one of the 5 sub-categories that resulted from thematic analysis of journal entries regarding coaching impact and coaching applications. Students' quotes used to support grit/resilience subcategory mention the importance of sharing individual goals with another person who shares the same commitment and the importance of keeping themselves accountable.
#17	Grit-O	75 (33 experimental and 42 control group)	No precise data (bar charts)		Based on improvement scores (post-test scores minus pre-test scores) the control group improved their grit level, while the advising group decreased. These differences ran counter to the hypothesis, although differences were not significant. A weak but negative correlation was evident between grit and both curiosity and creativity, meaning those with higher grit scores had lower scores for curiosity and creativity than those with lower grit scores.
#18	N/A; self-rating grit statements	2014 = 384 2015 = 435		In the module 'Cultivating Perseverance', students were invited to rate themselves in a series of statements based on the Grit-S (short) scale. Students were directed to view Duckworth's TEDTalk.	No grit-related results were reported. Students who completed more content (more quizzes) had an average higher university GPA and higher retention rate than students who completed less.
#19	Grit-S	108	Grit scores by groups of students (exam scores) 3.40, Perfect ($n = 26$) 3.34, Near perfect ($n = 10$) 3.38, Mostly ($n = 11$) 3.59, Often ($n = 24$) 3.56, Sometimes ($n = 15$)		No significant differences were found when comparing the final exam scores with the pre-course scores measured for grit and self-efficacy. The authors hypothesise that this is due to the fact that grit and self-efficacy assessment was only performed at the beginning of the course.
#20	Not clear which Duckworth version was used.	374	3.55 (Standard Deviation, sd = 0.49)		Significant gender differences in grit (short version), and *consistency of interest* were

				reported. Females were grittier than males, at all academic levels. Across genders, *consistency of interest* was lower than *perseverance of effort*. Athletes demonstrated significantly higher averages for grit (Grit-S) but also *consistency of interest*, compared to non-athletes.
#21	Not specified. Grit assessment included in a survey instrument to capture several student factors.	371		(Pilot study findings). Topological data analysis revealed five groups that differed by affective measures (grit being one of it). Group 1 was the largest and corresponded to the normative group. Groups 2–5 were considered to be non-normative. Group 5 was identified as being composed by students with higher levels of motivation, lower grit, lower extraversion and agreeableness, and lower physics identity. No further data on grit and the different groups was provided.
#22	N/A	interviewed 9		Grit was conceptualised as short-term motivation and as domain- and task-specific, instead of as a wider attribute. Qualitative analysis indicated that grit (persistence) was moderated by student's perceived instrumentality of a problem-solving task.
#23	Grit-S	129 (39 senior, 70 junior and 20 freshmen)	3.60 for Y1 (sd = 0.49) 3.73 for Y2 (sd = 0.47) 3.70 for Y3 (sd = 0.40)	(Preliminary results reported). On average, Y2 and Y3 students were grittier than Y1, but sample sizes varied greatly and no significant differences were found. Data was also analysed by generational status (first and second generation students) but no significant differences were found.
#24	Grit-O	60	3.33 (sd = 0.45)	Grit scores reflected a moderate to high correlation with the conscientiousness factor ($r = 0.59$, $p < .001$). A weak significant correlation was evident between grit and achievement in the course ($r = 0.24$, $p < .02$).
#25	N/A	28		Students' grit was observed by the lecturer assistant, via subjective behavioural assessment of students involved in a voluntary project abroad (engineering applied in a developing community).

(*Continued*)

Table 3. Continued.

# Paper	Grit instrument	Sample size, *n*=	Grit average (mean, and standard deviation where provided)	Grit (other aspects)	Findings (in narrative form)
					Students who went beyond the requirements showed a deeper understanding of the learning context.
#26	Grit-S (*perseverance of effort* only)	61 Experimental group $n = 31$ students Control group $n = 30$ students	Grit – *perseverance of effort* aspect only Experimental group 4.01 Pre-test grit 3.53 Post-test grit Control group 3.98 Pre-test grit 3.70 Post-test grit		Pre-test and post-test responses of the experimental and control groups were compared. The authors found that students in the experimental group were more perseverant than the ones in the control group (moderate effect size 0.30).
#27	Grit-S	55			No specific data on grit were reported in this paper.
#28	No instrument was specified	18			Students wrote application essays in response to a grit-related prompt, but no specific data was reported on grit in this paper.
#29	Grit-S	418 (500 = 71 first year, 429 from Y2 to senior years - but a few were excluded)	3.50 for Y1 (sd = 0.54) 3.43 for Y2 (sd = 0.49) 3.31 for Y3 (sd = 0.62) 3.43 for Y4 (sd = 0.61)		Grit was excluded from the 'Non-cognitive model' because the authors had identified a significant correlation with conscientiousness and used that construct instead. Grit among Y1 students was slightly higher than that of other students. No statistical testing was mentioned to ascertain statistical differences between groups.
#30	10 item scale (book reference)	60	4.18 for Y1 2.97 for Y3		First year students were found to be grittier than Y3, although no statistics were provided to identify if differences were significant. For Y3, a small effect size (0.248) was reported between grit and achievement (as measured by exam scores).
#31	Grit-S	10			Differences in pre and post-test scores were not statistically significant. No significant differences on grit were reported.

(Please note that the Paper citation can be found in Table 2 by cross-referencing the Paper #.)

Research topics

Most of the studies aimed to understand the impact of grit either as a predictor of academic success, such as the impact on grades, learning outcomes and performance ($n = 13$); or as a predictor of persistence and retention, meaning the student subsequently continued to be enrolled in an engineering degree ($n = 11$).

Some papers focused on how grit impacted the experiences of different demographic sub-groups of students, and assessed initiatives designed to better support those same groups. Such papers focused on gender ($n = 5$), engineering identity ($n = 2$), ethnicity ($n = 2$) or non-traditional students ($n = 1$). Out of three papers on teaching and learning, two addressed the alignment between student and staff attitudes toward teaching and learning, and one explored students' perceptions of problem solving. Three papers focused on programme assessment, and a final paper focused on the development of entrepreneurial attitude.

Population

As US-based researchers conducted a majority of the studies, the most frequent delineation of comparison groups used a North American format: freshman (year 1 or Y1), sophomore (Y2), junior (Y3), and senior (Y4). For the purpose of reporting in this paper for a global audience, year of study (Y1, Y2, Y3, and Y4) has been adopted and used consistently throughout to identify student level.

The majority of the analysed papers were conducted exclusively with Y1 engineering students ($n = 14$). Ten papers reported data collected from students at more than one year of study. On the other hand, four papers reported data exclusively from students in Y2 ($n = 1$), Y3 ($n = 2$) and Y4 ($n = 1$). One paper presented a summer bridge program for engineering freshmen (students who entered Y1) and reported the impacts of the program on students' first year studies.

Two papers reported studies with female students only, and other two papers included students as well as academic staff.

Methods and instruments used to assess and analyse grit

Quantitative. With just a few exceptions ($n = 7$), most studies implemented quantitative methodologies to assess grit ($n = 24$). Most quantitative papers presented average scores for grit, as a result of having: administered of one of the versions of Duckworth's Grit scale (Original or Short version); compared different groups of students; and/or analysed the relationship between grit and other significant variables (such as grade point average or conscientiousness) using correlation or regression analysis. Other quantitative methods to analyse grit were cluster analysis and topological data analysis.

Qualitative. Four papers assessed grit using qualitative methodologies. Two of these four papers used interviews – with one of the interview-related studies using grounded theory for analysis ($n = 1$) and the second using interpretative phenomenological analysis ($n = 1$). With regard to the other two qualitative studies, one analysed student's journal entries ($n = 1$) and the final study of this qualitative group used data collected via observation ($n = 1$).

Mixed Methods. Three papers reported mixed methods. Two of these three complemented data from grit surveys with interviews. The third paper of this group used data from a grit survey in addition to students' essay responses to grit-related prompts.

Grit instrument. The most frequently used grit instrument was Duckworth's short version ($n = 14$), followed by the original ($n = 6$). Complicating matters, five papers that reported having used an instrument either did not specify the name and version of the grit scale or used a scale with a different number of items than developed by Duckworth. One paper asked students to rate themselves regarding a set of grit statements, but no mention to an existing/standardised instrument was made.

Synthesis of the selected publications

As most papers were published in conference proceedings, findings were usually presented as being preliminary or as part of larger and complex research projects, making comparisons between studies difficult.

The following sections, describe and organise the papers by common research focus. A comparison between studies has been included in cases where reported data was sufficient to identify similarities and differences in research approaches. Three of the papers discussed grit, but did not report specific findings.

Qualitative approaches to grit

The papers that adopted a qualitative or mixed methods approach explored students' perceived grit in different contexts. In one paper, the lecturer observed students' grit behaviour in response to a grit scenario (Montoya, Sandekian, and Knight 2013).

Two papers focused exclusively on female students: one sought to understand how women's application essays with a grit prompt impacted their willingness to persist in engineering studies (Romanella and Novoa 2016), and another investigated women's grit in a coaching programme (Groh 2016).

One paper exploring students' motivations to study engineering found that students with a high entrepreneurial interest mentioned grit (persistence) as being a core attribute to excel in engineering (Call et al. 2017). Finally, one paper presented an alternative definition of grit because participants' perceptions of problem solving suggested that grit is domain- and task-specific, and also related to short-term motivation (Kirn and Benson 2018).

Grit and cognitive and non-cognitive factors

A few papers reported correlations between grit and either cognitive (e.g. academic outcomes) or 'non-cognitive' variables (e.g. personality traits). Positive correlations were reported between grit and: grade point average (GPA) (Chen et al. 2015); achievement (McDermott, Daniels, and Cajander 2015); and completion of homework (Bennett et al. 2013). The paper by Bracey et al. (2016) reported an increase in the retention rates of grittier underprepared Year 1 students, although no statistical tests were reported. However, other studies found no statistically significant differences between grit levels and academic performance reflected in exam scores (Bennett, Schleter, and Raman 2012; Holmes 2014), and grit and retention rates (Choi, Myers, and Loui 2016).

Two studies found grit to be positively correlated to conscientiousness (McDermott, Daniels, and Cajander 2015; Senkpeil and Berger 2016), and one study found grit to be negatively correlated with curiosity and creativity (Guilford, Blazier, and Becker 2015).

This line of work is highly relevant to engineering education, and is worth following up on, as these findings may help to inform the development of programs to support students in their journey to become engineers.

Programmes to develop students' psychological traits

Two papers presented programmes aiming to support engineering students' psychological preparedness. One of these programmes (Pierrakos 2017), delivered throughout one semester and directly focussed on supporting psychological well-being among Y4 engineering students, found that students in the experimental group rated themselves as more gritty (regarding, specifically, *perseverance of effort*) compared to the control group students; a moderate effect size was reported.

The other programme (Guilford, Blazier, and Becker 2015), also delivered during one semester, reported an increase of grit levels for the control group, and a decrease for the treatment group. However, these differences were not statistically significant. It is worth noting that the intervention developed for this programme was delivered as an academic development focus with an 'intrusive

advising' for a range of different psychological constructs (self-efficacy, curiosity, perseverance/grit, and creativity), thus it was not specifically designed to develop grit and these additional details might explain the results.

Although the two programmes were the same length, their grit findings are not comparable due to differences in both the: (1) populations involved and (2) grit instruments used. The first programme (Pierrakos 2017) was designed for Y4 engineering students and assessed only their perseverance; whereas the second programme (Guilford, Blazier, and Becker 2015) was designed for Y1 students and assessed their overall grit (including both perseverance and passion).

Profiling students

Two papers used grit scores in grouping students together. One paper (Desai, Shah, and Dhodi 2016) used quantitative methods to cluster students by their determination (measured as grit) and academic success (measured by students' grades/marks and IQ/intelligence quotient). This clustering was done to help lecturers identify distinct groups of students and adapt their teaching accordingly. The other paper (Choi 2016) used qualitative methods to explore students' individual experiences in their engineering degrees and categorise participants according to their attitudes towards an academic setback (specifically, having received a D or F in a required course).

Grit in different academic years

A few papers compared grit levels of students in different academic years. One paper (Chen et al. 2015) reported that grit was significantly higher in Y1 students, compared to other academic years. Two other papers (Senkpeil and Berger 2016; Sheridan and Carr 2017) reported higher levels of grit for Y1 students in comparison to others, but these differences between students were not statistically tested or reported. One paper (Lerner 2013) contradicted these findings; it reported findings (that were both preliminary and statistically non-significant) that, on average, Y2 and Y3 students were grittier than Y1 students. None of these studies analysed data longitudinally by following the same individuals over time, and this restricts the interpretation of the findings. However, some conference papers described longitudinal data being collected and said additional analyses were underway, therefore future reports may emerge.

Gender and ethnicity

As most research on grit aims to better understand its impact on academic success and persistence, a few papers focussed on underrepresented groups of engineering students.

Of the three papers reporting that female students were grittier than their male counterparts, two found statistically significant differences between genders (Bottomley 2015; Jaeger et al. 2010), and one did not (Choi and Loui 2015). One study focussing on minority students found a positive relation between personal motivations and grit (Bracey et al. 2016), but no statistical analyses were presented to support this claim.

Based on emerging findings, the study of academic persistence and success of underrepresented students appears to be a promising area for future research but the number of studies published to date in this area is not sufficient to draw conclusions.

Discussion

The results of this systematic literature review yielded one main conclusion – the research on grit in engineering education is inconsistent in their methodological approaches and findings. This poses limitations to the interpretation of findings across the set of studies included in this review. Inconsistency is reflected in different conceptualisations of grit, and in different data-reporting practices.

Inconsistent conceptualisations of grit

This systematic review of the literature suggests that grit has not been studied consistently in engineering education research, and that students' interpretations of grit are not reflective of Duckworth's definition.

Some quantitative studies have assessed grit by focussing on just one of Duckworth's sub-scales: (a) grit as *perseverance of effort* (e.g. Pierrakos 2017) or (b) grit as *consistency of interest* (e.g. Benson et al. 2017). This might suggest researchers are interested in specific sub-scales of grit, or that Duckworth's grit scale might not be the most relevant instrument for assessing engineering students' grit for the purpose of these studies.

Findings by qualitative studies that explored definitions of grit have found that, for engineering students, grit means being hard worker and resilient (e.g. Groh 2016); and that grit is associated with short-term motivation (e.g. Kirn and Benson 2018). These findings suggest that engineering students' conceptualisations of grit do not consider consistency of interest (passion) and perseverance for long-term goals, which contradicts Duckworth's definition of grit.

In addition, the studies that provided split scores for the two grit sub-scales reported lower scores for consistency of interest (passion) compared to perseverance of effort (perseverance) (e.g. Jaeger et al. 2010) among engineering students. These findings leave space to further explore the role of passion in engineering education and its role in student performance (e.g. Jachimowicz et al. 2018).

Finally, the two papers that addressed the relationship between grit and conscientiousness (McDermott, Daniels, and Cajander 2015; Senkpeil and Berger 2016) reported positive correlations between these two constructs. This aligns with what has been found in the larger body of literature on grit, suggesting that grit might be similar to facets of conscientiousness that include *self-discipline* and *achievement striving* (e.g. Credé, Tynan, and Harms 2016; Rimfeld et al. 2016; Schmidt et al. 2018). Eskreis-Winkler et al. (2014) have not denied this relationship, but have emphasised that grit differs from facets of conscientiousness by its 'extreme stamina in terms of particular interests and applied effort towards these interests' (2). Future extensive multi-trait studies could help test the validity of grit to engineering education.

The relevance of studying whether grit can be considered a domain-specific, instead of a domain-general construct, has been discussed in the literature. For instance, Duckworth and Quinn (2009, 173) suggested to 'ask respondents to answer items separately with respect to particular contexts'. Schmidt et al. (2017), in order to explore a measure of school-specific grit, adapted the grit scale by adjusting the phrasing of the items to the school context. They found that 'school-specific grit was a more valuable predictor for GPA than domain-general grit' (Schmidt et al. 2017, 8). Their findings encourage further research to assess domain-specific grit in other domains, such as engineering.

Inconsistent reporting practices of data analyses

This systematic literature review highlights that the impact of grit on engineering students' persistence, retention and academic success is not clear; in engineering education research, relationships between grit and impacts on performance have not been identified with consistency. This may be due to the limited number of papers included in the review and/or the type of publications reviewed. Most papers presented 'work in progress' projects that included grit as one measure amongst many others to assess students' traits, and published in conference proceedings. The level of detail provided in conference proceeding, particularly with regard to grit definition and assessment, has not been high enough to enable comparison between studies. Furthermore, in some studies, the findings have not been not well supported and claims have not been justified by adequate reporting of statistical procedures and outcomes – thus, more detail and more precision is needed in this realm, too.

One of the most consistent findings across the reviewed papers, nonetheless, has been that newly enrolled undergraduates are generally grittier than students in more advanced years, and that female students are grittier than male. Yet, there seems to be a lack of longitudinal and mixed method studies available to explore these patterns in ways that lead to cleat and robust findings.

Limitations and implications for future research and practice

The selection of papers analysed in this systematic literature review, finalised in March 2018, did not include doctoral theses and dissertations.

Although this review has not included all types of grey literature, it has identified grit as an emergent field in engineering education research. The review indicates that grit in engineering may not be studied in other parts of the world to the extent that it is being studied in the United States.

The majority of the records analysed in this review were conference proceedings, many of them reporting work-in-progress projects. It is expected that these works, in particular the studies supported by NSF, will yield longitudinal reports and more refined quantitative data. Ideally, this would make possible a meta-analysis of grit in engineering education. The authors of the present paper aimed, but were unable, to conduct meta-analysis during the research reported here due to having too few studies available that reported precise quantitative data. This is not unusual in engineering education research. In fact, 'in most research areas related to engineering students or engineering content, there are simply not enough studies of similar design to support meta-analyses' (Borrego, Foster, and Froyd 2014, 61). To build up the usefulness and credibility of engineering education research, researchers need to report research methods and analyses more clearly.

Based on the analyses conducted for this study, the authors have identified several promising avenues for further/future research:

- Regarding qualitative studies on grit, there remains ample room to explore the role of passion (*consistency of interest*) in engineering. Future work could include the development of a new instrument geared toward engineering and able to accurately assess 'engineering grit'.
- Studies exploring individual grit vs. collective grit (for instance in teamwork or project base learning contexts) are warranted. Working in teams is core to engineering practice. Studies on group's grittiness could provide useful insight for educators. How do groups of engineers keep passionate about their team and their projects and persist over time? For example, it would be interesting to understand how team's grittiness relates to co-regulated learning (Malmberg, Järvelä, and Järvenoja 2017) and socially shared regulation of learning (Hadwin, Järvelä, and Miller 2011; Panadero and Järvelä 2015).
- For researchers within UK and Europe, more studies could involve foundation year students (year 0 or level 3), following them through their transfers into 3 year degree programmes. Research on this could be of interest because such courses generally accept students who have lower academic grades and entry qualifications. This presents an opportunity to study the role of grit on learners with lower academic outcomes.

To help build the base of engineering education research in this area of grit – to make it robust, useful, valid and credible – those conducting research and publishing upcoming results on grit should:

- Explicitly state which instrument was used (Grit-O, Grit-S or other). If an existing grit instrument was modified in any way, the authors should explicitly state why and how was this important to their study;
- Be clear about which items reached statistical significance and what reaching significance implies in each case;
- Report means/medians, standard deviations/variance and effect sizes for each significant finding.

In order to better contribute to the advancements in the field of research, studies need better reporting of both instruments and retrieved data, even when they are presented as work-in-progress or in conference proceedings.

Overall, the construct of grit seems to have different definitions in engineering education. In many cases it has been defined as a synonym of *perseverance of effort*, which disregards the other side of grit – *consistency of interest*. This highlights a need for greater precision and specificity regarding the study of grit within engineering education research and across education research more broadly. Also apparent is a need to adopt a critical perspective regarding grit, how it is measured, and what it means for engineering students, educators and institutions.

Disclosure statement

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Notes on contributors

Inês Direito, Ph.D., is Senior Research Fellow at the UCL Centre for Engineering Education. She is a Psychologist working in engineering education research since 2007. Her main research focus on the development of transversal and professional skills; gender, diversity and inclusion; and, more broadly, how social and cognitive sciences can inform engineering education and practice. She is the Chair of SEFI's Special Interest Group on Gender & Diversity, member of the UK and Ireland Engineering Education Research Network steering committee, and Fellow of the Higher Education Academy.

Shannon Chance, Ph.D., is Visiting Professor and Marie Curie Research Fellow at the UCL Centre for Engineering Education, on career break from her permanent role as Lecturer in the School of Multidisciplinary Technologies at TU Dublin. She is a Registered Architect and former Professor of Architecture in the USA. Her main research interests involve identifying best practices in engineering and architecture pedagogy, enhancing and transferring these between fields, fostering diversity in the professions, and enhancing students' personal and epistemological development. She serves as Associate Editor for IEEE Transactions on Education and is on the governing board for the global Research in Engineering Education Network and the Editorial Board of the European Journal for Engineering Education. She has completed one Fulbright Fellowship and one prior Marie Curie Individual Fellowship, both at TU Dublin.

Manish Malik, SFHEA, Ph.D. (underway), is Associate Head of Student Experience at the School of Energy and Electronic Engineering, University of Portsmouth. His main research interests involve identifying best practices in technology enhanced engineering education, in particular: (1) collaborative and computer orchestrated individual and group learning, (2) their benefits for Project Based and Flipped Learning, and (3) the role of orchestration technology in making education more inclusive. He recently started the role of Associate Editor for *IEEE Transactions on Education* and is one of the founding members of the UK & Ireland Engineering Education Research Network. He is currently enrolled on his Ph.D. at Lancaster University in the area of computer orchestration of student learning.

ORCID

Inês Direito http://orcid.org/0000-0002-8471-9105
Shannon Chance http://orcid.org/0000-0001-5598-7488
Manish Malik http://orcid.org/0000-0001-8233-6357

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