European Journal of Engineering Education

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ceee20

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To cite this article: Sundara Kashyap Vadapalli, Frederique J. Vanheusden, Ahmed Tamkin Butt, Abdellatif Abdelgaied, Neil J. Mansfield & Katy E. Griggs (28 Aug 2024): *Thriving through trials and tribulations*: the impact of the '*Grand Challenge*' on engineering student resilience skills, European Journal of Engineering Education, DOI: 10.1080/03043797.2024.2397420

To link to this article: https://doi.org/10.1080/03043797.2024.2397420

EUROPEAN JOURNAL OF ENGINEERING EDUCATION
https://doi.org/10.1080/03043797.2024.2397420

Thriving through trials and tribulations: the impact of the '*Grand Challenge*' on engineering student resilience skills

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ABSTRACT

Resilience is considered of significant importance for student attainment and work-readiness. This study investigated the impact of Grand Challenge (GC) – an industry-based learning assessment for 1st and 2nd year Engineering students – on student resilience. Resilience scores and psychological distress were measured before and after the GC through questionnaires presented to students. Focus groups were conducted to assess GC's effect on student resilience qualitatively. Resilience scores in the questionnaires decreased slightly after GC, possibly due to less students completing the post-GC questionnaire. Interestingly, when discussing GC in the focus groups, students did feel GC helped them develop their resilience and understood the impact of resilience on their future career. Overall, the findings help establish GC as a challenge-based learning (CBL) intervention and the extent to which such CBL assessments may affect student resilience skills. The study provides the groundwork for future resilience training and assessment in higher engineering education through CBL events.

ARTICLE HISTORY
Received 1 September 2023
Accepted 21 August 2024

KEYWORDS
Resilience; pedagogical research; resilience-based intervention; grand challenge; challenge-based learning

1. Introduction

The need to deal with complex, unfamiliar challenges at short notice requires high levels of resilience within the engineering profession (Winkens and Leicht-Scholten 2023). Employees with higher resilience are less likely to face psychological stress and more likely to complete projects successfully (Liang and Cao 2021; Mubarak, Khan, and Khan 2022). Resilience also helps engineers develop their careers, especially when they are from a non-traditional background (Khilji and Pumroy 2019; Villa et al. 2020; Wilkins-Yel, Simpson, and Sparks 2019). This need to adapt to challenges and address setbacks, while somewhat universal across professional domains, merits a construct of resilience that is specific to the engineering field and a prerequisite in engineering education (van den Beemt et al. 2020).

From the start of their academic journey, engineers are expected to develop a form of 'career resilience' to cope with changes and learn new types of equipment, tools, and theories (Nieusma and Johnson 1996). Engineering courses are generally highly demanding of students, and therefore often developed with an emphasis to prepare students for the engineering profession (Wint and

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/03043797.2024.2397420.

Direito 2023). This involves training in professional skills and developing resilience (Wint and Direito 2023), Yet there still appears to be confusion within engineering academic communities about what student resilience encompasses, how it can be measured reliably considering other confounding factors such as student background, and how it can be incorporated in the curriculum (Hunsu, Carnell, and Sochacka 2021; Winkens and Leicht-Scholten 2023; Wint and Direito 2023). This confusion may cause higher levels of dropout and mental health problems compared to students in other courses, rather than improved levels of resilience within engineering student cohorts (Danowitz and Beddoes 2018; Hunsu, Carnell, and Sochacka 2021; Rosenblatt and Lindell 2021; Wint and Direito 2023). It may further tighten the bottleneck of sufficiently skilled employees entering the engineering profession (Hunsu, Carnell, and Sochacka 2021).

This study addresses some of the concerns regarding the implementation and assessment of resilience within engineering education. Building resilience is implemented using a challenge-based learning method (CBL – van den Beemt et al. 2023) within a supportive environment (Afroogh et al. 2021), which we have named the 'Grand Challenge'. The Grand Challenge is an industry-based project which runs over three weeks and is designed to improve student resilience skills, among other employability skills. Evaluation of the effect of Grand Challenge on resilience is based on a combination of demographic analysis, validated questionnaires (Connor-Davidson Resilience Scale – Campbell-Sills and Stein 2007 and K10 psychological distress scale Andrews and Slade 2001; Kessler et al. 2002) related to resilience and distress and thematic analysis of focus group interviews. The objectives of this study are:

(1) Measuring the impact of Grand Challenge on engineering students' resilience within the empirical and practical constraints of measuring resilience;
(2) Critically evaluating the possibility of influencing student resilience using a CBL programme; and
(3) Determining optimised methods to measure student resilience within an engineering education environment.

2. Literature review

Assessing an individual's resilience is contextually dependent (Prince-Embury and Saklofske 2013), but can be referred to as their ability to persevere against change and adversity (Carlson et al. 2012).

Resilience within the context of higher education (student resilience) has attracted academic enthusiasm for three main reasons. First, the generalisable role of student resilience in personal development and, subsequently, its interrelationship with social cohesion and sustainability is acknowledged within multiple contexts (Labrague 2021; Liu et al. 2019; Ungar and Theron 2020). Student resilience is also considered having a role in fostering social health and stability (Moya and Goenechea 2022). Second, the identifiable need for resilience in the contemporary context of higher education has been described previously (Dhar, Ayittey, and Sarkar 2020). This is affected by higher education undergoing momentous shifts owing to the pressures of digital transformation, the COVID-19 pandemic and their impact on economic stability and the interdependence between formal education and employability (Dhar, Ayittey, and Sarkar 2020). Third, the role of higher education institutions as an additional environment apart from the home and family environment to promote resilience is widely recognised (Henderson 2011; Twum-Antwi, Jefferies, and Ungar 2020). Nevertheless, the significance and seldomness of resilience research in engineering pedagogy is recognisable and requires addressing (Hunsu, Carnell, and Sochacka 2021; Winkens and Leicht-Scholten 2023).

There are, however, challenges to resilience training in higher education. First, the empirical conceptualisation of resilience remains a matter of widespread academic debate. Anderson (2015) disputed the concept of resilience and the discourse surrounding resilience on the grounds of its contextual plurality and conceptual limitedness. He encouraged a nuanced and critical approach

to its context-dependent application. Garrett (2016) and Gill and Orgad (2018) furthered this argument and contested the empirical validity of resilience, while criticising its potential for attributing individual responsibility to social and structural problems.

Another concern regarding resilience-based policy is the risk of depending on a 'one size fits all' approach and subsequently constructing resilience as a psychosocial 'panacea'. Anderson (2015) addressed this issue by emphasising that resilience may not be cultivated by virtue of one policy or program, as its multifaceted characteristics co-exist alongside other influencing factors and attributes. Additionally, Anderson (2015) raised the question whether resilience is sustainable long-term, or whether resilience is the immediate short-term outcome in dynamic psychological systems of risk and preparedness. These questions (if unaddressed) can affect significantly the validity and viability of any resilience-based intervention.

A third challenge is arriving at a standardised measurement of resilience, overcoming the barrier of sufficiently evaluating the impact of a resilience-based interventions. Apart from stressing the need for conceptual clarity of resilience and related constructs such as hope, Ong, Liu, and Cintron (2022) pointed to the lack of definitive measures of resilience and their appropriate adoption across different contexts. Though validated resilience scales exist (Connor and Davidson 2003; Friborg et al. 2003), the potentially dynamic nature of individual resilience may remain overlooked, under the influence of time and non-linear components of resilience (contextual circumstances, culture, and socioeconomics) which often remain hidden in prospective studies on resilience building. The evaluation of any resilience-based intervention will particularly be affected by this, as significant external factors not directly connected to the intervention itself but contributing to individual resilience scores will be ignored, thereby possibly resulting in ambiguous, uncertain result interpretation (Hunsu, Carnell, and Sochacka 2021). For example, the statement 'Resilience helps me overcome difficulties in life' is not valuable without further contextualisation of the factors determining the subjective conceptualisation which led to the statement in the first place. Another practical impediment, especially in the higher education context, is the ability of the researcher(s) to control for longitudinal exposure of the intervention in the same sample, while being consistently perceptive of (if not directly measuring or observing) external factors affecting resilience in individuals (Hendrickx, Schüler-Meyer, and Verhoosel 2023; Hunsu, Carnell, and Sochacka 2021; Winkens and Leicht-Scholten 2023).

A methodological workaround to these issues is possible. First, a suitable and practical intervention that students can engage with within the institutional environment needs to be identified. Developing a comprehensive solution which will holistically cater to the resilience training needs of all students will be challenging. Rather, an intervention consisting of different, inter-dependent and exchangeable exercises that can promote and evaluate resilience using various techniques and tools may be more appropriate.

Challenge-based learning (CBL) provides a feasible framework for such a solution. The conceptualisation of CBL has had a varied progression. Gallagher and Savage (2023) classify CBL as a pedagogic approach, which actively engages students with problem-solving skills, critical thinking, and participatory learning, in order to address real-world challenges through innovation, collaboration, and multi-disciplinarity. CBL extends traditional problem-based learning (PBL) by asking students to not only solve a (given) problem but also define a specific problem themselves and work out a solution (Kohn Rådberg et al. 2020). Further, CBL benefits from the involvement of external stakeholders/industry partners (Doulougeri et al. 2024). CBL is also an extension of the Conceive-Design-Innovate-Operate (CDIO) framework, which is an educational approach aimed at training engineers, through its focus on comprehensive learning that goes beyond the engineering fundamentals, and emphasises teamwork, reflection, social awareness, and personal development (Kohn Rådberg et al. 2020; van den Beemt et al. 2023).

Several studies emphasise the practicability of applying CBL within engineering education (Doulougeri et al. 2022; Hendrickx, Schüler-Meyer, and Verhoosel 2023; Membrillo-Hernández et al. 2019). CBL does not explicitly offer a decisive avenue for resilience training. However, incorporating an

assessment-oriented extension within the CBL framework may help formulate a dynamic educational approach that will allow engineering students to learn actively, and be thoroughly tested, on their engineering, employability, and resilience skills.

Authentic assessments provide a theoretical basis for such formulation. Authentic assessments can be defined as assessments that place priority on the student's ability to incorporate their outlook, core competencies, and knowledge in practical real-life situations, with an emphasis on professional development (Gulikers, Bastiaens, and Kirschner 2004). Previous studies showed successful implementation of authentic assessment in PBL within engineering education (dos Santos 2016; Woods 2012), leading to an improvement in student troubleshooting skills, teamwork, confidence, and communication skills. Incorporation of these assessments within a CBL environment may also enhance the feeling of ownership of their learning and skills development (Hendrickx, Schüler-Meyer, and Verhoosel 2023) Although the direct impact of authentic assessments and CBL on resilience has not been investigated rigorously, current literature provides promising directions for further empirical research (Clegg and Diller 2019; McArthur 2023).

To ensure the designed intervention addresses the effect of external factors satisfactorily, it needs to contextualise resilience measurements with prospective qualitative and quantitative research, both consistently implemented at a short-term and longitudinal scale (Carnell et al. 2020; Hunsu, Carnell, and Sochacka 2021; Tudor, Sarkar, and Spray 2020; Wint 2023). This approach will help researchers to evaluate the efficacy of a resilience-based intervention while maintaining a theoretically grounded and critical perspective of resilience theory and its contradictions, thereby boosting the validity of the intervention. From a quantitative perspective, Likert scale-based approaches such as the Resilience at University (Turner, Holdsworth, and Scott-Young 2017) and Connor-Davidson Resilience Scale (CD-RISC, Campbell-Sills and Stein 2007), have been used frequently. The former mostly pays attention to resilience within students when transitioning into higher education, whereas the latter performs an assessment of overall resilience that can be used within and outside educational settings. Qualitatively, resilience can be assessed through focus groups (Tudor, Sarkar, and Spray 2020), of which transcripts can then be analyzed through thematic analysis (Braun, Clarke, and Rance 2014; Wint 2023).

3. Methods

3.1. Grand challenge

Grand Challenge (GC) is an annual event involving an industrial partner held around the Easter period at our university. GC is undertaken by first- and second-year engineering students in mixed-year, mixed-discipline teams (combining mechanical, electrical and electronic, biomedical and sport engineering students). Each team comprises 10 students and an academic staff member acting as a non-executive director (NED). The NED-team relationship is designed to differ from traditional supervisor-student as each NED supervises only one team and is expected to act in an advisory role, mimicking the role of director in a business context. Students are grouped based on their attainment and attendance rates, ensuring a similar mixture of students within each team (Houghton and Dunne 2000).

The Grand Challenge can be considered a form of authentic assessment, incorporated within the framework of CBL. During GC, students are given three weeks to conceptualise, design and implement a solution for a real-life engineering topic within a specific industry. The first week of GC involves students familiarising themselves with their group members and deciding on their roles within the team (Figure 1). After being introduced to the double-diamond design model (Figure 2; Kochanowska and Gagliardi 2022), the team identifies a problem they are going to tackle within the real-engineering topic given to them. Teams are then given time to start developing an initial idea for a solution, discussing their progress with their NED daily. At the end of the first week, the students are formatively assessed on the problem they identified and initial solution by

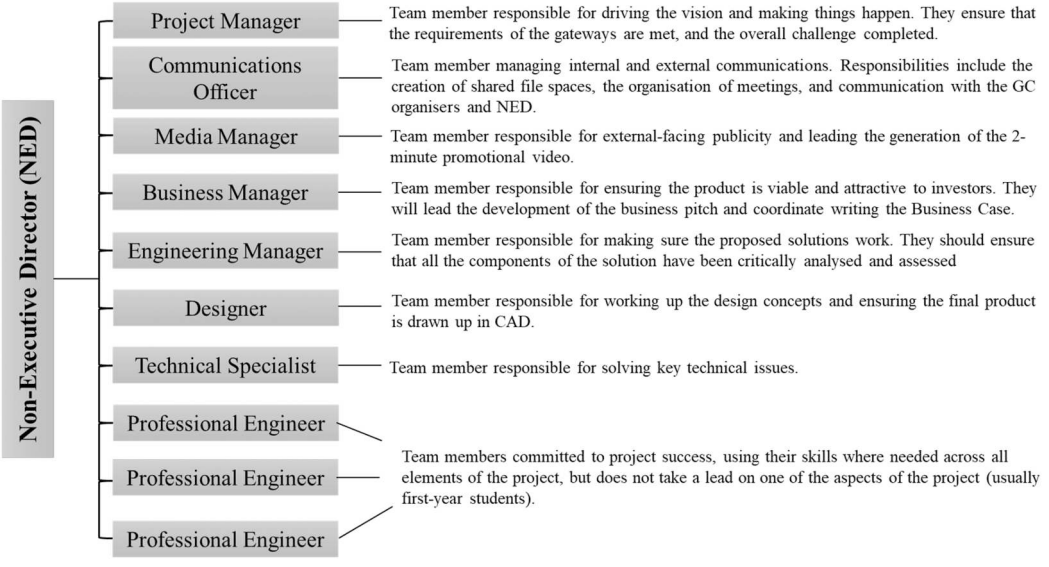

Figure 1 . Typical structure of GC student team, with individual roles allocated to students and an academic acting as non-executive director.

two academic staff members. These staff members check that teams have allocated a student to each role and identify a problem they wish to address based on the first of the double diamonds in the double-diamond model. Teams also indicate their target user(s) and stakeholder(s).

The second and third week of GC are directed towards developing a demonstrator, business plan and promotion video, again with daily reporting to the NED. At the end of the second week, students are again formatively assessed on their progress and teamwork. This assessment involves the same academic staff as in week 1. The academic staff will check students have ordered components they require to build their demonstrator, have developed a storyboard for their video and a draft of their business plan based on templates provided. At the end of the GC, each student team presents their ideas and solutions to assessors comprising academics and industry partners during a mock tradeshow, developed from the scenario that teams are seeking an investor to take their concept from demonstrator to production. During the tradeshow, students are assessed as a team on their demonstrator, business plan and video (Figure 3), alongside professionalism and project management by

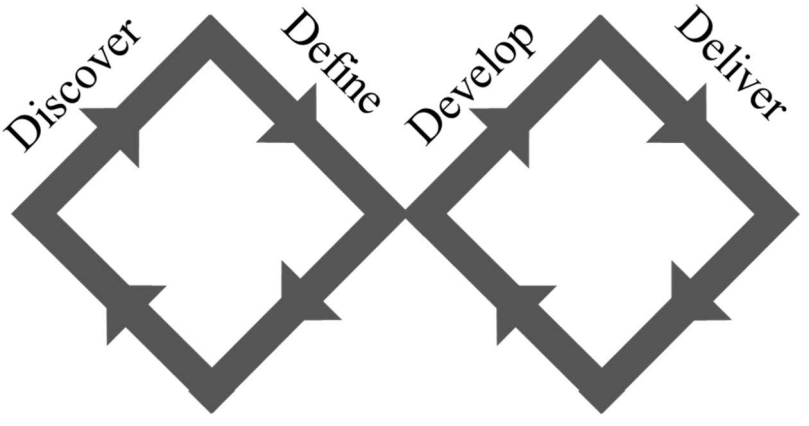

Figure 2 . Double-diamond design model (reproduced from Kochanowska and Gagliardi 2022).

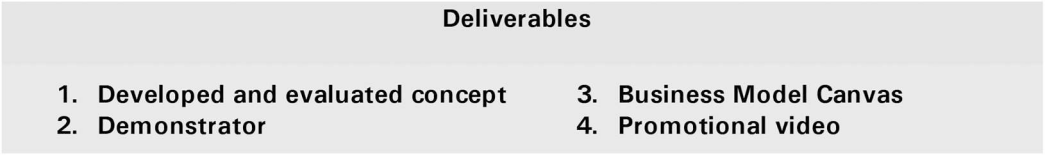

Figure 3 . Overview of GC deliverables as presented to the students in the GC manual.

two academics. Students are also expected to assess their own performance and the performance of their team members through a peer review activity.

GC is considered an intervention suitable for resilience training as it extends the student's 'comfort zone': a crucial feature in resilience training (Brooks, Brooks, and Goldstein 2012; Ishak, Yusoff, and Madihie 2020; Richardson 2002). GC extends engineering students' comfort zones through its collaboration- and communication-heavy nature, alongside addressing other employability skills such as business and marketing skills, which are important factors in making students work-ready (Murray, Pytharouli, and Douglas 2022). This is further supported by previous research highlighting the need for improving communication skills and attitudes towards communication in early undergraduate engineering students (Idkhan, Syam, and Hasim 2021; Kovac and Sirkovic 2017). Drawing insights from previous research, GC addresses core challenges concerning the professional development of engineering students (Valentine, Marinelli, and Male 2022) by introducing inter-disciplinary and inter-year collaboration to students, exposing them to contrasting knowledge bases, theoretical and practical approaches and learning experiences offered to students in different engineering courses. This helps them develop skills in working in professional interdisciplinary teams (Nancarrow et al. 2013). GC further sets out a framework for students to learn how to adapt to (negative) feedback and persevere against failure/hardships by discussing issues identified during the formative assessments with their team members and NED. This provides students with an empathic environment to learn from mistakes and improve their skills (Afroogh et al. 2021). Lastly, GC is set against a tight time constraint, allowing students to build skills in working towards tight deadlines (Bee and Hie 2015) within a stressful yet supportive environment (McEwen 2011).

3.2. Resilience analysis

A mixed-methods explanatory sequential design was implemented to analyze the impact of GC on resilience. Both quantitative and qualitative data were collected before (pre-GC) and after (post-GC) to gain understanding of the perspectives and behaviour of the general population. To maintain experimental consistency and methodological vigour, the data collection process was time constrained by design. For practical reasons, these constraints affected the overall size of the analyzable sample but furnished reliable datasets to address the research objectives. The study was approved by our local ethics committee. Participants gave informed consent before participating in the questionnaire and focus groups. Questionnaire data were collected anonymously and focus group interview transcripts were anonymised, with video and audio recordings discarded after transcription was completed and verified by at least two authors. All engineering students participating in the GC were allowed to join the study. The study did not exclude students suffering from mental health issues for its intention to study the effect of GC and similar CBL-based initiatives on an entire engineering student cohort. It was made clear to students that participation was fully on a voluntary basis. Our questionnaire also included reference to support services at our institution in case students identified themselves in severe distress.

3.2.1. Pre-GC

3.2.1.1. Questionnaire. Ninety-two students ($N = 92$) out of a cohort of 480 (19%) enrolled in an online questionnaire provided on the first day of GC. The questionnaire combined the validated CD-RISC 10

resilience scale (Connor and Davidson 2003; the list of questions is accessed from Campbell-Sills and Stein 2007 and can be found in the supplementary information) and the validated K10 psychological distress scale (questionnaire accessed from Andrews and Slade 2001 and can be found in the supplementary information, see also Kessler et al. 2002) with relevant demographics such as sex, ethnicity, year of study, course of choice and secondary educational background. These questions were included to measure student resilience and their psychological wellbeing at the start of GC, since resilience is affected by overall mood (Campbell-Sills and Stein 2007). Further studies have also suggested that resilience and study attainment can be affected by past (secondary education) performance (Salanova et al. 2010), being allowed to study a preferred course within a preferred institution (Ayala and Manzano 2018), and factors such as age, sex, ethnical and cultural background or household income (Ceglédi, Fényes, and Pusztai 2022; Chung, Turnbull, and Chur-Hansen 2017; Ross, Huff, and Godwin 2021; Wasonga, Christman, and Kilmer 2003). Although mental health status was not considered in the eligibility criteria, responses to the K10 psychological distress scale allowed for a consideration of notable statistical outliers, i.e. the effect of psychological distress on wellbeing on resilience scores.

3.2.1.2. Focus groups. Two focus groups with, in total, eight ($N = 8$) first-year students from our engineering cohort were conducted. None of the students had previously participated in GC. Participation incentives included a pizza of choice and entry into a lottery to win a gift voucher (Table 1). Students could select up to four time slots during which they would be able to participate in a focus group. Students were allocated a particular focus group based on their preferred time slot and availability.

For the focus group, a semi-structured open-ended group interview script was constructed, interrogating the expectations and concerns of students regarding GC before their participation, alongside their perspectives on resilience. The interview schedule was designed in accordance with the guidelines developed by Braun and Clarke (2006; 2012) and the five step-process by Kallio et al. (2016), for increased reflexivity and consistency, and reduced bias in questionnaire formulation and later interpretation. While previous evidence and the research objectives informed the interview schedule, it was also pilot tested for inter-rater reliability and further refinement. Examples of the questions that were included are: *1. Are you looking forward to GC? 2. How do you define resilience? 3. How will being resilient help you in your further studies/career? 4. What skills do you expect to gain or/and train by partaking in GC? 5. Are you anxious about partaking in GC?* Focus groups were recorded in audiovisual formats and transcribed for analysis.

3.2.2. Post-GC

The explanatory sequential design was repeated for the post-GC phase to measure its impact on resilience. For the quantitative sub-phase, thirty-one students enrolled ($N = 31$). Of these, nine students ($N = 9$) had already completed the pre-GC questionnaire. The post-GC questionnaire repeated questions asked during the pre-GC questionnaire, but also included open-ended questions allowing students to reflect on GC and its impact on their resilience and employability skills. These followed an amended STAR (Situation-Task-Action-Result) format (Brumm, Mickelson, and White 2005), adding reflective aspects specifically asking students to reflect on their Employability and Resilience skills, leading to what will be referred to as the STARER approach. Students were also given the opportunity to provide feedback on the organisation of GC itself.

An additional focus group involving three students ($N = 3$) was conducted to gain insights into the findings of the post-GC questionnaire and to contextualise the impact of GC on resilience

Table 1 . Overview of demographics for the pre-GC focus groups.

Participants	Course	Sex
8 ($N = 8$)	Biomedical Engineering: 5 Mechanical Engineering: 3	Female: 6 Male: 2

(Table 2). The inclusion criteria remained the same as the pre-GC focus groups with the exception that students were expected to have participated in at least 1 GC prior to the post-GC focus group. The participation incentives also remained unchanged. Two participants who participated in the post-GC focus group had already joined a pre-GC focus group. The third post-GC focus group participant had not joined a pre-GC focus group. Example questions for the post-GC focus group included: *1. What did you like/dislike about GC? 2. What is the main purpose of GC project/assessment? 3. Has GC helped you develop employability/resilience* skills?

A summary of the cohorts for each of the questionnaires and focus groups is provided in Table 3.

3.2.3. Data analysis

As questionnaire data distributions significantly varied from normal distributions (Shapiro–Wilk test, $p < 0.005$), they were analyzed through Kruskal–Wallis analysis of variance (ANOVA) tests between the variables within the SPSS 28 environment (IBM, USA). Significance was assessed at $p \leq 0.05$. A Wilcoxon signed-rank test was used to compare pre- and post-GC distributions between individual questions. Questions with binomial distributions within the demographics were analyzed using a Chi-square test.

The focus groups were recorded and transcribed for thematic analysis (Braun and Clarke 2006; 2012). The analysis was carried out by an iterative process of compartmentalising the corpus of research data derived from the focus group transcripts, identifying meaningful data, and labelling and codifying data for generating the themes separately by the lead and second author. Themes identified by both authors were compared and, where disagreements occurred, discussed with the remaining authors until convergence was achieved. The themes were refined and reviewed for narrative coherence and consistency and were analyzed through interpretation. Ultimately, thematic analysis enabled an in-depth exploration of the impact of GC by allowing further contextualisation of the statistical analyses, while enabling a theoretically congruent exploration of students' subjective experiences of GC and perceptions of resilience, (Xu and Zammit 2020), without undermining reflexivity or objectivity in interpretation.

4. Results

4.1. Questionnaires

Demographics for cohorts of both questionnaires are provided in Table 4. Distributions between Pre- and Post-GC demographics were not significantly different.

CD-RISC 10 and K10 scores for the entire question sets as well as individual questions within each set were compared between the pre- ($N = 92$) and post-GC ($N = 31$) cohorts. Figure 4 shows the distribution of answers (as percentages) for the CD-RISC 10 questionnaire. Figure 5 shows the distribution for the K10 questionnaire.

An overview of questions for which significant differences were found between the pre- against post-GC questionnaire is given in Table 5.

For the CD-RISC 10 resilience questionnaire, answer distributions evolved towards more negative responses in the post-GC questionnaire. Similarly, for the K10 questionnaire, post-GC questionnaire answers developing toward more negative feelings. For those students who completed both the pre- and post-GC questionnaire, CD-RISC 10 data showed no significant difference in distribution (Friedman test, $p = 0.251$) or pre- vs post-GC paired comparisons. K10 data showed differences in

Table 2 . Overview of demographics for the post-GC focus groups.

Participants	Course	Sex
3 ($N = 3$) Inclusion Criteria Engineering students who participated in the Grand Challenge	Biomedical Engineering: 3	Female: 2 Male: 1

Table 3 . Overview of participants for each experiment in the study.

	Pre-GC participants (total)	Post-GC participants (total)	Pre-and post-GC participants (total)
Questionnaire	92	31	9
Focus groups	8	3	2

distributions amongst individual questions (Friedman test, $p = 0.005$), but no differences in pre- vs. post-GC distributions.

Answers to open-ended questions corresponding to student perceptions of GC showed mixed feelings about GC. Students showed mixed feelings about the topic (engineering heritage), with 42% disliking it and 26% liking it. Based on their written responses, students expressed they enjoyed the potential to train their employability skills (29%) but found the timing of GC to be too close to exams (29%). While meeting new people was considered a positive aspect of GC (26%), some respondents complained about the lack of engagement of other group members (23%).

Table 4 . Comparison of demographics pre- vs. post-GC questionnaire.

Demographics	Groups	Pre-GC (%)	Post-GC (%)	*p*-Value
Age	18–21	82.6	74.2	0.77
	22–25	14.1	19.4	
	26–30	1.1	0	
	Above 30	2.2	3.2	
	Not stated	0	3.2	
Sex	Male	79.3	67.7	0.51
	Female	20.7	29.0	
	Not stated	0	3.2	
Nationality	British	72.8	77.4	0.34
	Non-British European	14.1	3.2	
	Non-European	13.0	16.1	
	Not stated	0	3.2	
Ethnicity	Arabic	3.3	0	1.00
	Asian	6.5	9.7	
	Black	16.3	9.7	
	Latin	0	3.2	
	Indian	7.6	12.9	
	White	58.7	58.1	
	Other	7.8	3.2	
	Not stated	0	3.2	
Course	Biomedical	22.8	22.6	0.87
	Electrical and Electronic	20.7	19.4	
	Mechanical	51.1	58.1	
	Sport	5.4	0	
Undertook foundation course	Yes	43.4	41.9	0.61
	No	56.5	50.1	
Entry qualifications	UK-based general secondary education (A-level)	69.6	67.7	0.97
	UK-based technical education (BTEC)	17.4	6.5	
	EU-based secondary education	2.2	0	
	(non-EU) secondary education	5.4	6.5	
	Other	5.4	16.1	
	Not stated	0	3.2	
Optional placement	Yes	41.3	38.7	0.58
	No	58.7	61.3	
Engineering as first-choice course	Yes	77.2	71.0	0.94
	No	22.8	29.0	
Our institution was your first-choice university	Yes	50.0	41.9	0.23
	No	50.0	58.1	
Year of study	Year 1 (level 4)	58.7	61.3	0.31
	Year 2 (level 5)	41.3	39.7	

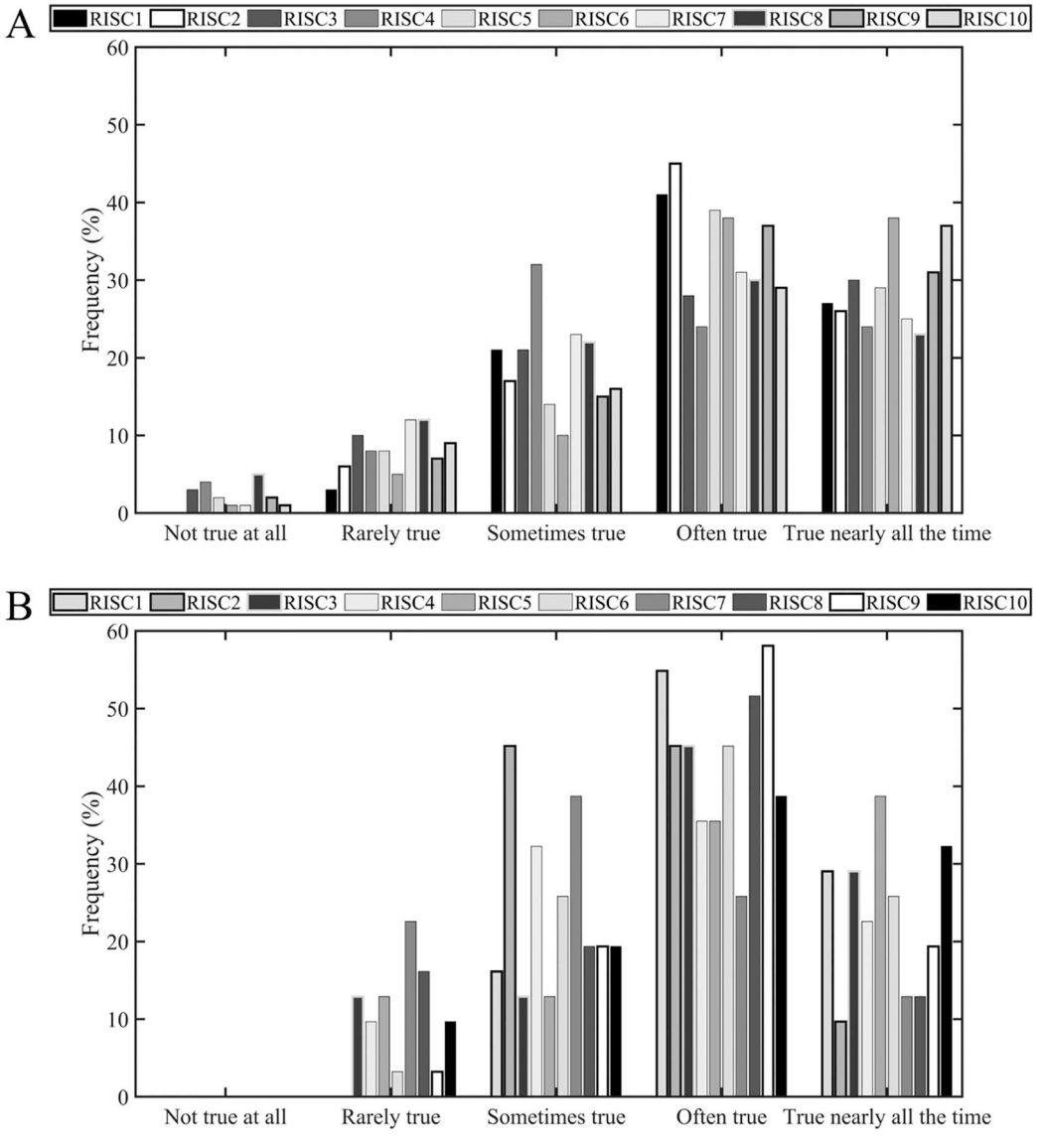

Figure 4 . Distribution of answers to the CD-RISC 10 questions for pre- (A) and post- (B) GC questionnaires.

Table 5 . Overview of questions with significant differences in answer distributions between the pre-GC and post-GC questionnaire participants.

CD-RISC 10	I can deal with whatever comes my way	$p = 0.02$
	Under pressure, I stay focused and think clearly	$p = 0.03$
K10 questionnaire	About how often did you feel depressed?	$p < 0.001$
	About how often did you feel everything was an effort?	$p < 0.001$
	About how often do you feel so sad that nothing could cheer you up?	$p < 0.001$
	How often did you feel worthless?	$p < 0.001$

Based on answers to the STARER questions, 84% of respondents believed that a situation occurred during GC that helped them develop resilience, particularly through working in groups with people from different course backgrounds and balancing working towards tight deadlines

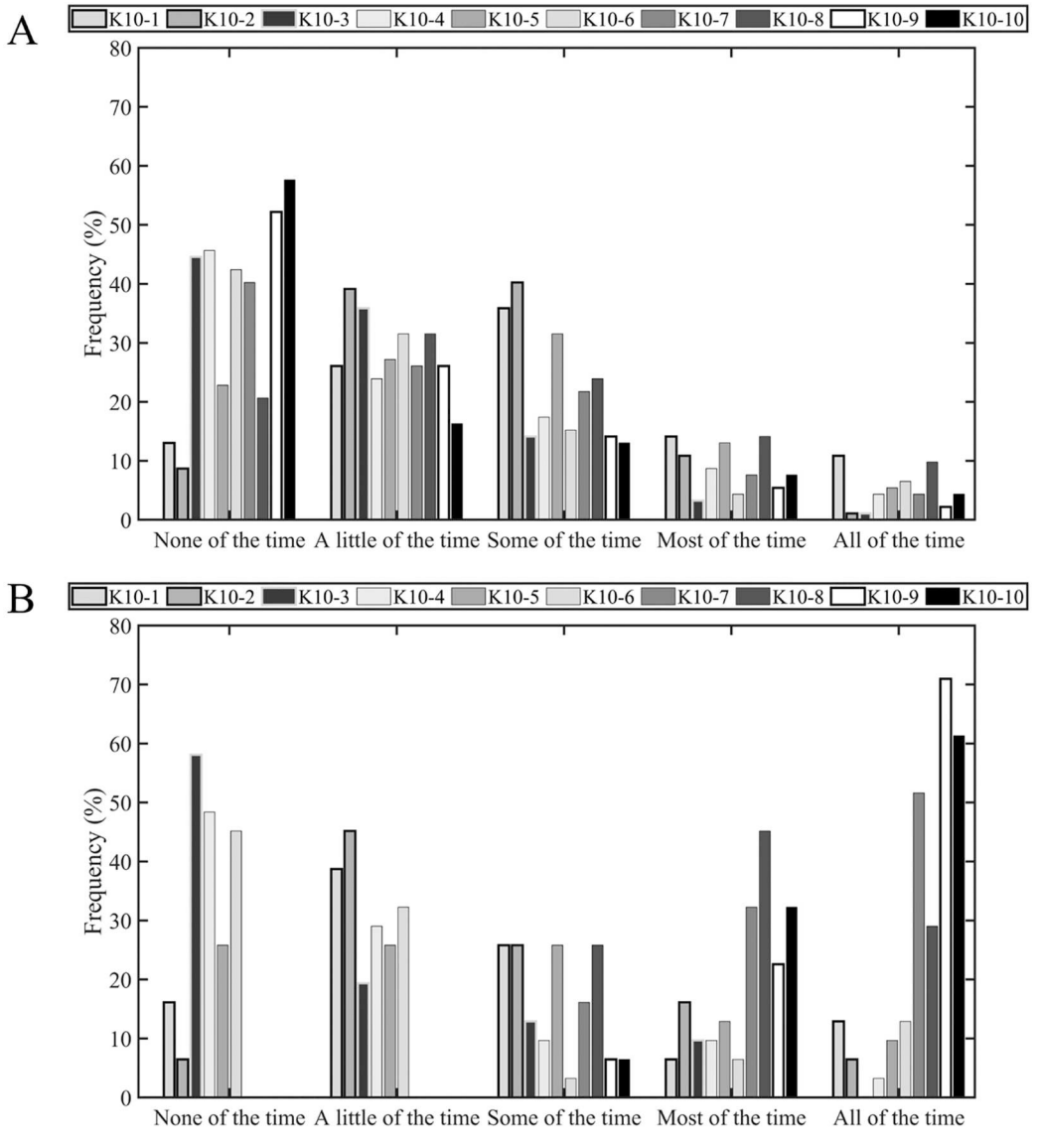

Figure 5 . Distribution of answers to the K-10 questions for pre- (A) and post- (B) GC questionnaires.

with personal matters. About 87% of respondents believed GC helped them develop employability skills, particularly communication and business skills.

4.2. Pre-GC focus groups

The pre-GC focus group explored the expectations and causes for potential concerns and enthusiasm of students participating in GC. It consisted of first year students who were enrolled in biomedical and mechanical engineering courses. After providing a background to GC, students were asked questions regarding their participation in GC and their perceptions on resilience. Thematic analysis recovered two superordinate themes (Table 5):

(1) GC as a learning opportunity – with the following subordinate themes:

(i) Industrial impact and employability
(ii) GC as a source of stress and anxiety

(2) Resilience – with the following subordinate themes:
(i) Resilience in everyday life
(ii) Resilience by virtue of identity (Table 6)

4.2.1. GC as a valuable learning opportunity

4.2.1.1. Industrial impact and employability. Students unanimously agreed that the most immediate and recognisable outcome of partaking in GC is its industrial impact and the impact on their employability skills. GC allows students to engage directly with a relevant industrial problem and present their case to academics and partnering industry organisations. Hence, it is reasonable for students to recognise the impact of GC on their industry experience and employability. More specifically, student MR0833 mentioned that '[GC] will be an experience where it will put us in an industry work-type of environment where we are expected to meet some kind of conditions that we would usually be facing in a real industry job', showing that the student finds GC a good indicator of what they can expect in an industry environment. FA0833 concurred:

> Going into the industry is like a step-by-step process of getting ready to be in the industry and doing well and relying on each other, so I think it's that process, which will help us to be our best when we go into the working field,

indicating that GC prepares them to become members of the engineering profession and helps them face the environment in their working field. SF0833 believed that GC will provide them with the experiences that will shape their understanding of a career path that is most applicable to them, thereby reiterating the point of GC being a valuable learning opportunity:

> I look forward to seeing what it feels like to work in the industry, especially since I've not yet decided if I would like to go into industry one day or stay in it in a research position or maybe go work in the hospital or something like that. So, it would be vital for me to get a feel for what it would be like to make the right decision for my education.

Students also recognised GC as a suitable avenue to engage with employability skills' training. FA0833 mentioned: 'The specific skills I associate with the Grand Challenge are teamwork with patience, understanding and communication', showing their perception on the potential impact GC will have on their employability and identifying several leadership and soft skills associated with GC. MR0833 added more emphasis to the employability aspect of GC by relating it with the experience of undertaking an actual job, thereby distinguishing it from other forms of assessment:

> [GC] will put us in a very different environment and try to kind of replicate the 9:00–5:00 or something along those lines, whatever it will be. I think it will be useful to receive skills from any other group project, but just a bit more in depth and more focused on kind of the employability skills as well.

The interdisciplinary and collaborative aspects of GC were also recognised by MA0833. Additionally, they expected GC to offer them valuable learning opportunities and provide an avenue for further developing their skills.

> I think it will be fun, getting to learn new things … just the reason that we are from different courses, and we will be applying different knowledge, we [biomedical engineers] can learn from the electrical and the mechanical engineers and they can learn something from us as well. I am looking forward to working together, learning different skills, and exchanging them.

Table 6 . Overview of superordinate and subordinate themes discovered through thematic analysis and percentage of participants agreeing per subordinate theme of pre-GC focus groups.

Superordinate theme	Subordinate theme	Percentage of participants agreeing (total: 8 participants)
GC is a learning opportunity	Industrial impact and employability	100%
	GC is a source of stress and anxiety	87.5%
Resilience	Resilience in everyday life	100%
	Resilience by virtue of identity	62.5%

4.2.1.2. GC as a source of stress and anxiety. About 87.5% of students reported that partaking in GC will involve some form of stress and anxiety. Some participants highlighted the specific sources of stress within GC. SF0833 noted how domineering team members and lack of inclusive communication pathways can negatively affect student self-confidence: 'Overpowering personalities. Especially from second years who might think you are incompetent as first years to provide input on the project. I think that would be my personal anxiety'. Other students raised similar concerns regarding collaboration and cooperation. For example, MR0833 reflected: 'What if I'm not matched with people who want to do extremely well in the project? Then I would potentially end up being a bit wasted because of others not matching the same level of enthusiasm'.

Adding to the significance of teamwork, time and unfamiliarity were identified as potential stress factors, as commented by SE0833: 'We only get one week to come up with the design. We get two weeks off. We need to have something to do for those two weeks, otherwise we will be stuck'. Similarly, FA0833 emphasised time being a factor of stress, while also highlighting the uncertainties surrounding GC and the barriers to potential success:

> The first is time, because out of five weeks, two are Easter. Which means if we are not well prepared, we don't have anything to do during the holidays. So, we need to plan and organise in the first week. The second is, what if something does not work out, what if something goes wrong. We are imagining a product, and there's loads that can go wrong.

4.2.2. The significance of resilience

4.2.2.1. Resilience in everyday life. All participants agreed with the conceptualisation of resilience as a skill that gives individuals the capacity to positively cope with adversity, through adaptation or perseverance. All students agreed that they encountered/actively encounter situations in life that test their resilience and encourage them to be more resilient. Some students provided how their lives within and outside of the university context needs them to be resilient.

MR0833 has explained how resilience is a feature of their life and enables them to be determined about achieving their goals in the face of adversity and barriers. They elaborated on how being in the university helps them manage their time and responsibilities, thereby training them to proactively engage with resilience and develop it further:

> I feel life has taught me a lot about how to train my resilience and how to keep going even if I'm sick or have a cold or don't feel like it. But I feel like it (university) does train us to have a better resilience over managing time and having a lot of different responsibilities to balance.

That resilience is significant to their life as a university student was reiterated by BM21323. They have noted that they expect academic responsibilities in the university to be incremental, particularly in their course of choice, and that resilience is a skill that will help them cope with student life:

> Resilience has been my entire experience with the university. I've never lived away from my parents before. I've never been this independent before and that's definitely caused me, made me adapt and I think grow as a person. I'm also aware that my course is one of the more difficult courses that you can take at university and it has been challenging. But I have been able to get a lot better and I see it as a form of resilience because I couldn't possibly think of living my life any other way.

4.2.2.2. Resilience by virtue of identity. From the focus groups, 62.5% of students confirmed that resilience helps them cope with unique challenges they encounter by virtue of their identity. While for some the identity was rooted in culture, for others it was rooted in gender. MA0833 elaborated on the challenges (such as intolerance) of being an international student by providing some personal anecdotes. They also stated that resilience helps them deal with real life situations where they feel as if they are not accepted for who they are:

> So, I came here many years ago. And as many people now are more tolerant to people from different countries, when I came here, I have listened to a lot of different things and I think I've built resilience for like trying not to

> listen those things and just going forward without being bothered about what someone said. I think it's not easy being the students from outside.

The significance of being a woman in a field traditionally dominated by men was accepted by most of the female students (83%). FA0833 suggested how generational differences could invigorate regressive gender norms in their industry:

> Newer generations do respect the fact that women can be in every field. But when you go into their industry, the positions, the director positions are for men. And they're from the older generation. So, they feel like they can discriminate.

Students then reported how being resilient will help them cope with existing gender disparities and challenges of being a woman in a male dominated field. SF0833 stated how being resilient not only will help them navigate through the field of engineering as a woman, but also as a crucial skill that will help them succeed.

> As a woman in engineering I expect resilience to help me a lot especially once we start working. And then, if you would like to become a prominent figure in the engineering field, resilience would be a big part of that I would expect.

Overall, students agreed to a common definition of resilience, and recognised its value in their personal and professional lives by describing how being resilient in general will help them cope with challenges that are (in many ways) context-dependent and person-specific.

4.3. Post-GC focus groups

As per the pre-GC focus groups, thematic analysis identified two superordinate themes from the post-GC focus groups:

(1) Impact of GC – with the following subordinate themes:
   (i) Challenges pertaining to GC
   (ii) Opportunities offered through GC
(2) Resilience – with the following subordinate themes:
   (i) Impact of GC on resilience
   (ii) Resilience beyond GC (Table 7)

4.3.1. Impact of GC

4.3.1.1. Challenges pertaining to GC. All students agreed that GC posed some challenges. GC requires students to engage with their group members (assigned by the department) to tackle an industrial problem and present their case to academics and partnering industry organisation(s). The challenges pertaining to GC are multifaceted.

SF0833 highlighted how their course of choice posed visible disadvantages in the context of GC, enabling them to not only work harder but also made to feel a lesser contributor, as opposed to their group members who had a considerably greater working knowledge of the problem:

Table 7 . Overview of superordinate and subordinate themes discovered through thematic analysis and percentage of participants agreeing per subordinate theme of post-GC focus groups.

Superordinate theme	Subordinate theme	Percentage of participants agreeing (total: 3 participants)
Impact of GC	Challenges pertaining to GC	100%
	Opportunities offered through GC	100%
Resilience	Impact of GC on resilience	100%
	Resilience beyond GC	100%

> I like to work in interdisciplinary engineering group. However, of all the first years from different engineering sectors, I felt like I was the one who had to work the most to keep up with them. Since we [biomedical engineers] do anatomy and chemistry, it's hard to keep up with people who have done electrical or mechanical courses. They had the sense that we couldn't offer as much as them and we had to do a lot of back-end tasks.

ID523 reiterated the similar sentiments to what SF0833 expressed, reporting further issues owing to the natural differences between the group members and explained further their difficulties to keep up with their group members and keep an open channel of communication: 'The second year were doing the whole job. I was kind of kept in the dark about the project and I had to try to understand what's going on'.

The subordinate theme ultimately indicates that communication, compatibility of GC with course and perceived or operational knowledge and in-group dynamics experienced by students, contributed to significant difficulties when engaging with GC.

4.3.1.2. Opportunities offered through GC. Despite the challenges, all students unanimously agreed that GC was a valuable experience and as an assessment, offered them unique opportunities and meaningful hurdles to overcome for their development as a student and professional. SF0833 indicated that GC provided them with appropriate industry exposure and that the experience will be insightful for their further professional development: 'Grand Challenge was a nice taste of the industry, particularly as a student, as I am not sure if I want to go to industry or do research'.

ID523 reported that GC gave them the practical environment of being a professional engineer, and emphasised how it was unique as an assessment in its ability to provide them with that practical experience: 'It was the only assessment that made me feel, like working engineer, like meeting with team members and trying to build/invent something'.

SE0833 also explained how GC specifically helped them engage with a range of employability skills and in training them, particularly those pertaining to team building, in-group communication and presentation: 'Grand Challenge helped me engage with employability skills like negotiating ideas, feedback and summarise and putting everything together during presentation and communication'.

Overall, due to the nature of GC as a relatively longer, practical assessment where students were required to work with a team to engage with an industrial problem, they believed that it gave them insights into professional life, preliminary industry exposure, and a foreground for their development in the field.

4.3.2. Resilience

4.3.2.1. Impact of GC on resilience. Students unanimously agreed that GC positively impacted their resilience by providing them with an avenue to train their resilience. They further highlighted the importance of resilience to deal with certain challenges posed by GC itself. SF0833 reflected on how GC helped them train their resilience by pushing them out of their comfort zone and enabling them to adapt while allowing them to be an efficient contributor and effective member of the group. Following the key challenge reported by SF0833, i.e. the course of choice being a notable disadvantage in their engagement with GC, they indicated how GC enabled them to adapt and overcome their hurdles: 'I think the Grand Challenge helped me train resilience throughout, because it was three weeks of not doing anything related to your discipline, not using the knowledge of your discipline, but still being an effective group member and adapting'.

ID523 also reported that GC enabled them to engage with components of resilience by helping them address between-collaborator conflicts, as well as overcome their limitations while practicing patience: 'It gave me a lot of patience, to not let disputes affect work and deal with them and to handle limitations'.

4.3.2.2. Resilience beyond GC. Similar to the Pre-GC focus group outcomes, all students agreed that they encountered/actively encounter situations in life that test their resilience and encourage them

to be more resilient. Moreover, all students agreed that their experiences at university and the resources it provided are sufficient for training their resilience in the context of their academic life. They also agreed that challenges are important for personal and professional development, as long as they are able to be resilient and overcome said challenges in healthy and constructive ways.

SF0833 suggested that a healthy relationship with life's challenges and the ability to be resilient are necessary for individual growth, ultimately implying that challenges are a natural part of existence, and they are important to develop resilience, while being resilient itself is necessary to address the challenges in the first place: 'To me resilience comes with life. Life's going to be challenging and we need them to grow as humans and to prosper. To get through the challenges, you need resilience, and they go hand in hand'.

SE0833 related to SF0833's comments on resilience and they reported that the university may not specifically contribute to further resilience training, apart from what they are already gaining (in this context) from their academic life at the university: 'I agree with everything SF0833 said. Also, apart from my academic life and what I am already doing at the university, I don't think the university can do anything in addition to help me train my resilience skills'.

5. Discussion

This study assesses the effect of GC, a three-week, industry-related, multidisciplinary team-based and assessed project, on resilience skills within first- and second-year engineering students. Resilience was assessed by asking students to join a focus group before and after GC, alongside completing a questionnaire on the first and final day of GC.

Apart from demographics-related questions, the pre-GC questionnaire included the CD-RISC 10 and K10 questionnaire. The CD-RISC 10 questionnaire was selected since, although specific resilience questionnaires exist for measuring resilience within a higher education environment (for example Turner, Holdsworth, and Scott-Young 2017), these questionnaires investigate the extent of student resilience when entering or experiencing an academic environment. The main purpose of this study was to evaluate resilience at a more general level, working towards an evaluation of how academic practices such as GC can help build student resilience as part of their development towards becoming professional engineers. The K10 distress scale has been used in previous studies measuring levels of distress and its relationship with resilience in undergraduate students, showing that students with higher resilience suffered less distress compared to students with low resilience scores (Bore et al. 2016).

To provide further opportunities to highlight the effect of GC on resilience, students were asked to reflect on how a particular situation/task during GC helped them gain employability and resilience skills. These open questions were based on the STAR approach, which is often used in interviews and can be considered a means for developing employability skills by preparing students for professional interviews (Brumm, Mickelson, and White 2005). The traditional STAR approach has often been modified, including adding opportunities for reflection or summarising main take-aways (Apple et al. 2021). Focus groups were organised to help corroborate and further explore the questionnaire findings through triangulation (Brown et al. 2015; Oliver-Hoyo and Allen 2006)

An integration of the findings of the pre-GC and post-GC data provided a comprehensive empirical perspective on the impact of GC on student resilience. The overall findings also provided insights into the study's limitations as well as the challenges of measuring the validity of resilience-based interventions in a higher education context.

5.1. Questionnaires

From a statistical point of view, the participation for the post-GC questionnaire was low ($N = 31$) and the comparison of the pre- and post-GC results is limited by a small number of students participating

in both the questionnaires ($N = 9$). Therefore, the findings ultimately reveal the overall statistical behaviour of year 1 and year 2 engineering students, without providing the possibility to compare rigorously the effect of GC on resilience at an individual level. While the participation rates in this study are limited, they do not differ from other work in the field, and the challenges surrounding student participation in educational research are well established. Saleh and Bista (2017) observed that factors such as student interest, timely reminders, and expectation of rewards influenced online survey response rates in higher education research, in addition to survey structure, communication methods, and perceived assurance of privacy and confidentiality. These observations, alongside contextual factors such as the full schedule of GC, may help evaluate the response rates of pre- and post-GC surveys to some extent and provide directives to improve participation rates in future studies.

Overall, analysis shows a decrease in overall resilience scores in the post-GC questionnaire for some of the CD-RISC 10 questions. There may be several reasons for this. First, GC and the post-GC questionnaire were completed close to the end-of-year exam period, with some students stating anxiety about the upcoming exams due to the lack of preparation time because of GC. This was indicated by students in the open-ended questions within the post-GC questionnaire. In a similar vein, other research has shown that resilience scores for individual students do not necessarily increase, and indeed may decrease, over the academic year (Fowler, Goldsberry, and Handwerker 2020). Another reason could be the cohort completing the post-GC consisted of students who generally feel less resilient compared to those completing the pre-GC questionnaire and considered the post-GC questionnaire to express their opinion about GC and/or their own resilience. This suggestion is founded on two observations: (1) the generally high score on resilience questions in the pre-GC questionnaire and (2) the insignificant differences found when comparing the (limited) number of students who completed both questionnaires. The latter also appears to deny that GC would directly negatively impact student resilience (or makes them more aware of their level of resilience). Ultimately, an interpretation of outcomes may be unsubstantial due to inexhaustive research data and lack of opportunity for participants to test their resilience again in a new situation as the sample point was immediately following the intervention. Finally, an alternative explanation is allowable considering that most students agreed that GC helped them build resilience and employability skills based on their responses to open-ended questions in the questionnaire. This view is also supported by the focus group data. Indeed, these findings further illustrate the challenges of constructing 'resilience' as a well-defined individual psychological characteristic that can be measured as a somewhat self-contained variable and subject to methodical and yet highly consequential external interventions.

5.2. Focus groups

A qualitative exploration of the themes allowed for a contextualisation of the statistical data analysis with a focus on person-driven (student) conceptualisations of resilience based on individual circumstances and personal worldviews, alongside student perspectives, concerns and expectations regarding GC.

5.2.1. Industrial impact and employability

GC can be described as an authentic assessment (Gulikers, Bastiaens, and Kirschner 2004) and tool to enhance challenge-based learning (CBL). GC allows students to engage with an industrial problem in engineering, and utilise their academic vigour, training, and competencies in the direction of problem solving and collaboration skills within a short time frame. Additionally, it tests their ability to communicate their work and findings through professional demonstrations. Hence, it can be established that GC closely follows CBL framework with the extension of authentic assessment. In a systematic review of authentic assessments by Sokhanvar, Salehi, and Sokhanvar (2021), authentic assessments showed a positive impact not only on the employability skills of

students but also their learning experiences. The current study highlights how GC differs from conventional assessments and emphasises student expectations to use GC for professional development.

All students felt that GC was a unique experience, allowing them to operate as a professional engineer. They also believed that GC was an industrial precursor and provided them with a valuable opportunity to engage with and demonstrate their core skills, knowledge and communication and interdisciplinary collaboration in a practical scenario. Ultimately, GC and similar assessments can be valuable in training the employability skills of engineering students and enhancing their learning experience.

5.2.2. GC as a source of stress and anxiety

Students viewed GC as a source of stress and anxiety, primarily because of the challenges in overcoming time constraints and potential in-group discord. The stressful nature of group assessments has been widely covered in higher education literature (Pitt et al. 2018), particularly in the context of peer assessment, which also features in GC. However, considering that resilience training was the basis of enforcing these challenges in the first place, GC aids in training the students' ability to acclimatise themselves to challenging and uncertain work-environments through adaptation, time management, coping with individual differences and bridging communication barriers. The positive outcomes of such group assessments on the performance and development of students (Pereira, Flores, and Niklasson 2016; Tumpa et al. 2022), and the positive effect of research projects on student communication skills (Carter et al. 2016) were highlighted in past literature.

Apart from time constraints, students felt that the most challenging aspect of GC was to bridge disciplines in a domain environment where their core skills and knowledge base were not optimal. As a result, students felt as if they were not able to make contributions as significant as their peers towards challenging problem solving in the group assessment. These challenges can be considered unique owing to the design and philosophy of GC as a form of assessment. However, GC led to experiences and concerns that are generalisable in the context of group assessments. Hassanien (2006) reported that the elements of group assessments that are outside of the control of those being assessed – such as engagement, cooperation, and communication of group members – caused much stress and negative perceptions. Students who partook in GC expressed similar concerns. Hence, while student opinion on the impact of group work and assessments was largely positive, a more organised approach to tackle these issues may be beneficial.

5.2.3. The significance of resilience

Upon conceptualising resilience as a skill that gives individuals the capacity to positively cope with adversity, through adaptation or perseverance, students expressed that GC helped them train their resilience skills. As a corollary, they stated that resilience was also equally important in addressing some of the fundamental challenges they faced during GC. The experiences of students and their perspectives of resilience illustrate the multidimensionality of resilience as a construct and the complexities in training resilience as a professional and life skill. As an assessment, GC follows the pattern of the findings reported in studies focusing on resilience-based interventions in higher education. A meta-analysis by Ang et al. (2022) revealed that resilience-based interventions that focused on enhancing social competencies garnered significantly positive results, as well as those that are didactic and dialectic in nature. While the data garnered in this study is not empirically sufficient to suggest that GC has a direct causal relationship with resilience, it can be reasonably argued that it offers an overall positive learning experience and may aid in resilience training within the context of personal and social factors for its participants.

5.2.3.1. Resilience in everyday life. Students conceptualised resilience as a skill that gives individuals the capacity to positively cope with adversity, through adaptation or perseverance. Consequently, they identified resilience not only as an important professional trait but also a life skill. In

that regard, the challenges, and uncertainties of everyday life as well as the unique challenges of student life in the contemporary world were highlighted. These views fit both conceptually and operationally within resilience theory (Carlson et al. 2012; Seery and Quinton 2016).

5.2.3.2. Resilience by virtue of identity. The participant accounts elaborated on the importance of social identities in shaping life experiences which in turn contribute to unique challenges in their personal and professional lives. The identities were ascribed to different constructs, such as gender and being an immigrant, and accordingly defined their everyday challenges by virtue of who they are. For instance, the female students emphasised on the challenges of being a woman in the engineering field due to social and cultural reasons. They also voiced concerns over encountering regressive individuals (and even superiors) at their future workspace, prompting them to work harder to prove their competence. Their views align with the findings of Mozahem et al. (2019), which reported evidence for barriers in the social and professional settings of women who opted for a career in engineering. Similarly, Marson, Ferris, and Dirisu (2022) highlighted the unique psychosocial as well as socioeconomic challenges faced by immigrant students – such as fewer opportunities for congeniality, greater isolation, and occasional animosity – and the participant accounts follow the findings closely. Students reiterated the importance of resilience to overcome the unique challenges faced by them by virtue of their identity. Past studies also exemplified the significance of resilience to cope with challenges based on identity and the resulting socio-economic adversities. Martin et al. (2022) illustrated the influential outcomes of resilience training in immigrant students and similar conclusions were formed in the context of women in engineering by Wilkins-Yel, Simpson, and Sparks (2019), thereby signifying resilience as a potentially valuable skill to cope with challenges based on identity.

5.2.3.3. Resilience beyond GC. The participant accounts supported the need for taking a critical stance on resilience theory and contest suggestions of taking a monadic approach towards resilience. The findings of this study fit within the arguments of Anderson (2015) on resilience. The pedagogic and consequential value of resilience training interventions in higher education can be recognised, while critically restricting resilience to constructs that are shaped and nurtured by individual life experiences, contexts and motivations and steering away from conceptualisations rooted in attribution bias.

Based on students' comments, GC appears to contribute to resilience training. While, at this stage, there may not be sufficient empirical evidence to establish GC as a viable intervention to meet the resilience needs of students, it provides an avenue to explore the long-term effects of GC on student resilience and its evolving conceptualisation within the context of engineering education.

This implies that resilience training is a complex issue and may not be laden with concrete causal characteristics and reveals the institutional boundaries of resilience training and implementing resilience-based interventions, as well as researching them. This conclusion provides some transferability of the results and is analogous to the challenges associated with resilience training in other contexts (Forbes and Fikretoglu 2018; Hartmann et al. 2020; Prakapienė and Markelienė 2024).

5.3. Implications

Although limited to a single student cohort, this study shows the potential of using a CBL-based framework in combination with authentic assessment to evaluate student resilience. While students' self-perceived resilience went down based on the pre-GC vs. post-GC questionnaire, students in focus groups identified the GC to help them build resilience. Reduced resilience in the post-GC questionnaire could indicate students becoming more aware of their level (or lack of) resilience, which can be used by educators to set up additional frameworks to help make students aware of their level of resilience and build resilience skills. Future studies and other educational institutions

could attempt to set up similar initiatives to assess their student resilience levels and help engineering students build resilience within a work-like environment.

The study has shown that a mixed-methods analysis of initiatives to assess resilience can aid in grasping the effectiveness of these initiatives in building resilience and making students aware of their levels of resilience. It is therefore recommended that future studies within this field use mixed-method approaches to evaluate their student resilience enhancement implementations.

5.4. Limitations and future work

This study focused mainly on analyzing the effects of a CBL-based authentic assessment on engineering student resilience skills by comparing quantitative and qualitative data before and immediately after the intervention. Future work will involve analyzing reflections of students on Grand Challenge and its impact on their resilience in a longer-term perspective (one year after completing the Grand Challenge).

Another way of assessing resilience interventions would be through observational studies. For the Grand Challenge, this would have involved observing students while working on the project and during their interaction with assessors and the NED. Unfortunately, these data were not collected for this study. However, future studies could evaluate the effectiveness of observational studies compared to 'pre vs post' studies on evaluating resilience.

6. Conclusion

The study confirms Grand Challenge (GC) to be a unique and useful authentic group assessment within the framework of Challenge-based learning (CBL), which supports professional and personal development of engineering students. Concrete conclusions on the long-term impact of GC on resilience cannot be made. However, the findings of the study revealed that GC may aid in resilience training and pave a path for rigorous future longitudinal research in the area. The study also highlights the challenges of conducting research on resilience (particularly in the context of higher education), but most significantly, demonstrated the need for criticality in conceptualising resilience and resilience-based interventions in engineering education.

Data availability statement

Data will be made available upon request.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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