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# The Impact of Students' Grit & Project Ownership on Students' Learning Outcomes in Maker-based Cornerstone Engineering Design Courses


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Abstract

The increasing presence of makerspaces in university campuses is encouraging engineering educators to incorporate making activities and projects to their curriculum. Making activities and projects allow engineering educators to offer students authentic, experiential learning opportunities that foster collaboration, creativity and innovation and can help students develop critical skills such as teamwork, problem solving, research, and entrepreneurial, leadership and management skills. This current study explores the impact of students' grit and project ownership on their learning outcomes over and beyond students' Big-Five personality traits in a cornerstone engineering design course that is based on making projects. The results indicate that grit as a higher-order construct is not associated with students' academic success or level of contribution in their team's projects in a collaborative, authentic learning environment. Also, the results indicate that the personality traits of agreeableness, extraversion along with students' adaptability to changes in life circumstances is associated with their development of intellectual and emotional ownership of their making projects. However, project ownership was not associated with students' academic success or level of contribution to their team's projects.

Keywords: Engineering Design Education, Grit, Maker Movement, Maker Education, Project Ownership

## Introduction

### A Background of the Maker Movement and Makerspaces

The emergence of the maker movement has impacted many domains and spheres of societal life. Its impact can be felt on education, economy, healthcare, and the increase in accessibility to science fields (American Society for Engineering Education, 2016). The promise that maker movement holds for education is its ability to "democratize access to the discourses of power that accompany becoming a producer of artifacts" [20, *p*. 500] by providing students with more agency over their learning (Dougherty, 2013), encourage learning across disciplines (Martin, 2015), and attract students to study STEM disciplines (Schad & Jones, 2020). The emerging maker movement has the ability to transform education by providing students with more agency over their learning and situating them in creative and stimulating experiences (Dougherty, 2013). By situating learners in creative and stimulating experiences (Dougherty, 2013), the maker movement empowers many people to create high quality craftwork and facilitate user-driven innovation (Aldrich, 2014; Baldwin & von Hippel, 2011). The maker movement has also been credited as being a potential transformative path to developing interest in engineering (S. Jordan & Lande, 2013) (Martin, 2015) as it provides for practical opportunities for the public to apply engineering principles in everyday life (Browder, Aldrich, & Bradley, 2017; Kohler, 2015), increases knowledge of production processes, and reduces the barriers of entry to markets (Hagel, Brown, & Kulasooriya, 2014).

Making as a pedagogical approach provides unique opportunities for educators to incorporate pedagogies that places the student at the center of the learning process such as project and problem based learning (Vossoughi, Hooper, & Escudé, 2016). Making activities also highlights the importance of experimenting and the social aspect of learning as opposed to traditional models of education that sees learning as a process of internalization in part of the individual and neglects relationships between the individual learning and society, environment, and the world (Lave, 1991; Dewey, 1916). Learning through making activities can also bridge a divide that exists between formal and informal education (Halverson & Sheridan, 2014), and provide a platform that facilitates theoretical and practical learning (Taheri et al., 2020). Also, making is a process of creative problem solving and design that can help educators integrate the disciplines of science, engineering and arts in educational programs and curriculums (Vossoughi & Bevan, 2014).

The emergence of the maker movement has led to an explosion of Makerspaces across the globe (Sheridan et al., 2014). Makerspaces are informal sites for creative production in art, science, technology and engineering, where people of all ages and experience meld digital and physical technologies to explore ideas, learn technical skills and create new products (Sheridan et al., 2014; Dougherty, 2013; Lisa Brahms & Werner, 2013). In the past decade makerspaces have been opening in museums and science centers (Lisa Brahms & Werner, 2013), universities (Forest et al., 2014; Wilczynski, 2015; Wong & Partridge, 2016), libraries (Noh, 2015; Cao, Wu, & Stvilia, 2020), and independent non for profits organizations (Halverson & Sheridan, 2014). These spaces "modify the conception of traditional sites of production and recast the notions of studio, workshop, laboratory, gallery, and atelier into new settings for the integrated design, production, and distribution of products" [17, *p*, 6] (Dougherty, 2013).

The presence of makerspaces in university campuses can be traced to the creation of FabLabs at the Massachusetts Institute of Technology (MIT) by professor Neil Gershenfeld (Halverson & Sheridan, 2014). Today, the FabLab foundation supports the creation of new FabLabs around the world and work to provide resources for users of the space to generate designs and transform them to products with-in house fabrication tools (Halverson & Sheridan, 2014). Makerspaces situated in university campuses are often described as Academic makerspaces to distinguish them from industry, community, and K-12 makerspaces (Wilczynski, 2017).

Universities open makerspaces as physical locations that foster social networks that improve the active learning component in the engineering program (Taheri et al., 2020) , situate students in authentic learning environments  foster collaboration and peer-learning, offer experiential learning environment (Wilczynski, 2017; Jensen, Özkil, & Krestine, 2016; Stager, 2013) which helps students build confidence through deep engagement in environments that provide access to exploration and fabrication technologies (Blikstein, Kabayadondo, Martin, & Fields, 2017). Moreover, makerspaces help blend traditional and digital skills with arts and engineering, creating a learning environment with multiple entry points for participants that lead to innovative combinations, juxtapositions and uses of disciplinary knowledge helping to break down disciplinary boundaries (L Brahms & Crowley, 2016; Sheridan et al., 2014). Makerspaces also allow learners to see tinkering and reflective practice as essential aspects of the learning process (McGrath & Guglielmo, 2015). Academic makerspaces also contribute to student retention and diligence by fostering innovation and entrepreneurship within the engineering curriculum, engage corporate partnerships to ensure the transfer of knowledge gained through the undergraduate curriculum to real-world applications, and establish a network of collaborations across the academic institution (Pines, Sullivan, & Nogales, 2015). Academic makerspaces are also utilized to provide training programs for instructions, technicians, managers and entrepreneurs (Taheri et al., 2020).

Engineering educators are also interested in integrating a maker component to their programs to attract a more diverse group of students, increase student retention and engagement, improve student performance and grades and increase student engagement (American Society for Engineering Education, 2017). Making activities help students develop broad skillsets beyond the engineering curriculum including: teamwork, creativity, innovation, collaboration, critical thinking, project management and systems engineering (Pines et al., 2015) problem-solving and research skills; nurture entrepreneurial, leadership and management skills; and introduce students to prototyping methods (Taheri et al., 2020). Engineering educators also see many values that learning activities that involves making can benefit their students such as helping students develop a maker mindset, giving students more agency, situating students a learning experience that is relevant and interesting, and facilitate the design of action-based and interdisciplinary learning environments (American Society for Engineering Education, 2017; American Society for Engineering Education, 2016).

Aiming to capitalize on the benefits that makerspaces bring to formal education institutions, the University of Ottawa opened its own on-campus makerspace in September 2014. The university intended to create a space that fosters innovation, promote multidisciplinary projects, provide access to prototyping facilities, encourage and facilitate students' entrepreneurship, and provide a space for students to realize their designs and acquire and practice new skills, and knowledge. The makerspace adopted a business model that granted free access to all students on campus, and dedicated Sundays to community engagement. Through exposure to the makerspace and other design spaces, students can collaborate with like-minded peers and participate in a community where they will find a lifelong learning opportunity. All spaces are open to students with little restrictions on the use of equipment and participants for personal or academic making projects, offering students opportunities to join and sustain the makers community of practice and learn from it if they wish.

Study's context

Despite the enthusiasm for the integration of making activities into education and the growing body of research on the opportunities making activities provide for engineering education, there has been little research on the development of making programs in engineering, and there remains a need for a more in-depth analysis of students' learning experiences with making activities in formal educational contexts (Papavlasopoulou, Giannakos, & Jaccheri, 2017; Bevan, 2017). Among the research gaps in the literature pertaining to the integration to and impact of making projects in education is the lack of quantitative studies focusing on the impact of the making activities on learning using measurable learning outcomes (Papavlasopoulou et al., 2017; Schad & Jones, 2020). This article aims to contribute to the literature on the impact of the maker movement in education by exploring the impact of a certain student characteristic on their learning outcomes in two cornerstone engineering design courses that has integrated making projects and activities as the central theme of their learning environment.

This article explores the impact of students' grit on students' academic success as reflected in their final marks in the course, level of contribution to their team's project as assessed by their peer assessment marks, and development of project ownership. In addition, the article explores the relationship between students' development of project ownership and their academic success and level of contribution to their team's project in cornerstone engineering design courses that have integrated making projects and activities as the main theme of its' curriculum. We study the impact of these two constructs over and beyond the Big-Five personality traits.

The site of the data collection and the study is the University of Ottawa's faculty of engineering. The faculty had worked to integrate two cornerstone engineering design courses at the first- and a second-year level. Both courses are client-centered and prototype-based. Students work in group settings. They get an opportunity to work with a real client from the Ottawa community. They meet with their client several times during the semester to determine their needs and receive feedback based on their conceptual drawings and prototypes. Teams are expected to generate three prototypes, with the final prototypes judged by external judges on the faculty's Design Day. The projects projects are biomedical, mechatronic, civil or software in nature most of the time. They can include mechanical, electronic, hardware and software parts. To accomplish this, 3D printers, laser cutters, microcontrollers, mills, drill presses, etc. can be used.

Grit

The first construct considered in this study is Grit which consists of two dimensions: perseverance of effort defined as "individuals' tendencies to keep working towards long-term goals" (A. Duckworth, Peterson, Matthews, & Kelly, 2007) and consistency of interest is defined as "Individuals' tendencies to pursue the same or similar activities over time" (A. Duckworth et al., 2007). Grit has been found to predict career changes, drop out of life commitments (Eskreis-Winkler, Shulman, Beal, & Duckworth, 2014), students' grade point average (Duckworth & Quinn, 2009), engagement with work (Suzuki, Tamesue, Asahi, & Ishikawa, 2015), self-regulated learning and past and present academic achievements (Wolters & Hussain, 2015). The perseverance of effort subdimension of grit has also been found to strongly predict academic adjustment, college grade point average, college satisfaction, sense of belonging, faculty-student interactions, students' intent to persist, and is negatively related to students' intent to change majors (Bowman, Hill, Denson, & Bronkema, 2015). While the consistency of interest subdimension was found to predict career changes in adults (Duckworth & Quinn, 2009; Bowman et al., 2015). The motivation to explore the impact of the grit construct on students' learning outcomes in engineering school stems from the fact that the study of engineering is hard for incoming students as it presents students with various academic challenges which requires high levels of persistence, self-discipline (Direito, Chance, & Malik, 2019). Due to the challenges that engineering students face during their years in engineering school, engineering education researchers have explored psychological factors that influence students' achievement in engineering programs (Hsieh, Sullivan, Sass, & Guerra, 2012).

Despite the great interest and attention that the grit construct has received which allowed it to capture public imagination and influence education policy through multiple bestselling books and articles about the importance of grit in determining an individual's success in life (Ivcevic & Brackett, 2014; Jachimowicz, Wihler, Bailey, & Galinsky, 2018; Credé, 2018), there have been few studied that has focused on studying the grit construct in the engineering student population (Direito et al., 2019). Studies on the grit construct in an engineering education setting found that grit can predict academic success in an introductory programming course (McDermott, Daniels, & Cajander, 2015), and is affect by students' engineering identity and feelings of belonging to engineering (Verdín, Godwin, Kirn, Benson, & Potvin, 2018). At the same time several studies have indicated that grit is not associated with engineering students' SAT scores, nor is associated with retention in engineering school (Choi, 2018).

Project Ownership

The second construct considered in the study is project ownership which in an education context refers to students' assumption of responsibility of their learning process, commitment, engagement, loyalty, sense of belonging and self-identification with their educational program or project (Wiley, 2009; D. I. Hanauer, Frederick, Fotinakes, & Strobel, 2012). Project ownership is a complex term that involves the students response to an educational environment (D. I. Hanauer et al., 2012; David I. Hanauer, Graham, & Hatfull, 2016). The construct of project ownership includes aspects of engagement, agency, personal connection, the recognition of community and disciplinary value, and positive emotive responses (D. I. Hanauer et al., 2012; David I. Hanauer & Dolan, 2014). Project ownership as a variable was found to differentiate into two factors: the content factor and emotional factor (David I. Hanauer et al., 2016), as it includes not only personal connectivity, agency, problem solving, social interaction and a sense of personal achievement but also increased emotional valence for the educational experience (David I. Hanauer & Dolan, 2014).

Student's development and experience of project ownership results from a complex interaction between the student and the educational environment (D. I. Hanauer et al., 2012) and is dependent on several factors including student's control over decision making, personal agency and amount of responsibility that a student has in the learning environment (Cooper, Blattman, Hendrix, & Brownell, 2019). Three features of a learning environment contribute to students' development of project ownership: discovery, iteration and collaboration, with the last two features being responsible for students' development of emotional ownership of their projects (Corwin et al., 2018). A growing sense of project ownership helps students become more tolerant of obstacles and to persevere when facing challenges (Ryoo & Kekelis, 2018; Corwin, Graham, & Dolan, 2015) which in turn increases students' self-efficacy and motivation (Corwin et al., 2015), encourage students to pursue a long-term career goals in science (D. I. Hanauer et al., 2012), and helps students achieve a better understanding of the unpredictability of scientific research (D. I. Hanauer et al., 2012). Moreover, Ownership of the learning process can sever as a stimulus for problem solving and self-directed learning (Savery & Duffy, 1995).

Studies on course-based undergraduate research experiences argue for providing students with more agency in their learning process which will lead to positive outcomes such as increasing students' resilience and encourage them to pursue a career in sciences. In this study, students were situated in an authentic learning environment that allowed them to select their projects and make decisions related to the development of their prototypes. This learning environment provided for an ideal opportunity to investigate the relationship that students' Big Five personality traits and grit have with their development of intellectual and emotional project ownership. Moreover, we wanted to examine students' project ownership predictive power of students' academic performance. In the case of this study, we wanted to explore the influence that a students' personality has on allowing them to have a feeling of intellectual and emotional ownership over their design project in an authentic learning environment. We will explore aspects of personality traits that relate to perseverance and persistence.

The study presented in this article is part of a research project that have been investigating the impact of certain students' characteristics on engineering students' learning in a maker-based curriculum. The study explores the impact of non-cognitive measure's – grit – impact over and beyond students' Big Five personality traits to predict three learning outcomes: students' academic success, level of contribution to their team's project and project ownership. In a previous study, we explored the impact of two non-cognitive measures, students' grit level and goal orientation in explaining students' academic success in a making-projects based design course, we found that grit as measured by the Grit-S scale has a weak relationship with students' academic success in the courses understudy and that only the perseverance of efforts was a positive predictor of students' final marks (Authors, 2020b). One of the hypotheses for the weak association between the grit construct and students' learning outcomes is that the grit scale used doesn't fully capture grit. The study provided more empirical evidence to (Credé, Tynan, & Harms, 2017) criticism of grit for the lack of a grit measure that can capture grit in the way that it's conceptualized by (Duckworth et al., 2007), and that the perseverance of effort dimension of the grit construct has more criterion validity than consistency of interest (Credé et al., 2017). Another criticism of Angela Duckworth's (Duckworth & Quinn, 2009) Grit-S scale is directed towards the items of the scale that measures the consistency of interests subdimension for its failure capture the individual's purpose, desire and interest in the context and fails to place significant emphasis on measuring the goal-orientation element of the grit construct (Muenks, Wigfield, Yang, & O'Neal, 2017; S. L. Jordan, Ferris, Hochwarter, & Wright, 2019).

In this article we also try to assess if a more up to date measure of the grit construct would still yield similar results. In this study, we use the Triarchic Model of the Grit Scale (TMGS) (Datu, Yuen, & Chen, 2017). Datu et al. (2017) developed a new measure of grit after observing that grit might manifest itself in different ways in different cultural groups and to investigate how grit operates in collectivist settings. This study aims to explore if students' grit level as measured by the (TMGS) can predict students' academic success or project ownership. The study also tries to investigate the association between project ownership and the students' academic success in a making-based engineering design course.

## Research Questions

The research questions addressed in this study are:

- Can grit as measured by the TMGS predict students' academic success and development of intellectual and emotional project ownership over and beyond students' Big-Five personality traits?
- Do intellectual and emotional project ownership add incremental predictive validity for explaining students' academic success and level of contribution to their team's project?

## Materials and methods

### Participants and Data Collection

Data collection for the study was conducted in the fall semester of 2019. A total of 132 students participated in the study. 25 (18.9%) were female students. 36 students were first-year students, 74 were second-year students, 15 were third year students, and 7 were fourth-year students. Participants were registered in first- and second-year introductory engineering design courses that aimed at offering students an authentic learning environment. Before collecting any data, ethical approval for the research was obtained from the University of Ottawa's office of research ethics and integrity review board. The principal author shared the questionnaire links with the students at the beginning of the semester. Participation was voluntary. Students were not incentivized to participate in the research. Students were also free to elect to not participate without being subject to any penalties and they were also made aware that they could choose to be removed from the study at any time and data related to them would be deleted.

The data collection process was divided in two parts. In the first part, students had to complete a questionnaire in the second week of the course. The first questionnaire was organized as follows: The first page presented students with the consent form, which outlined the purpose of the research study and its' conditions, students' who elected to agree to the research's terms and condition proceeded to view and complete the questionnaire. The second page contained demographic questions which asked students about their names, year of study, gender and what course were they registered in. The third page included elements of the TMGS which contained three subdimensions: perseverance of effort, consistency of interest and adaptability to situations. The Big-Five personality traits data were obtained from the professors as they had administered a personality assessment exercise at the first week of the semester to facilitate team building. The second part of the data collection process was administered at the end of the course to assess students' project ownership. The questionnaire used in the second part included demographic questions that asked students about their name, the course they were registered in, and elements of the project ownership scale developed by Hanauer et al. (D. I. Hanauer et al., 2012).

Procedure and measures

The Big Five Personality Traits:

As part of the team building process of the course student had to complete an online questionnaire in the first week of the semester right after they had selected their team members. The questionnaire was developed by the Individual and Team Performance (ITP) lab at the university of Calgary (T. A. O'Neill & Allen, 2011). The ITP lab's questionnaire is based on Goldberg's (Goldberg, 1999) International Personality Item Pool (IPIP). The measure consists of 24 items for each of the Big Five personality traits. The tool uses a five-point Likert scale ranging from 1 (very inaccurate) to 5 (very accurate). The measure intends to capture the same content as the NEO Personality Inventory (Costa & McCrae, 1992). The mean reliabilities for these scales based on the sample data in the IPIP database (N = 21,588) were 0.76 and 0.87 for facets and factors, respectively (O'Neill, 2007). Students' Big Five personality traits were assessed as part of the course's curriculum. This exercise was part of the team building phase at the beginning of the course. We collected the Big Five personality traits data pertaining to the students' who have elected to participate in the research and completed both steps of the data collection at the beginning and end of the course.

Academic Success:

Students' academic success in the course is assessed by looking at students' final course grade which consists of their project mark adjusted to account for their individual contribution to their team's project using their peer assessment mark, midterm and final exam's grades and their client's assessment of their work.

Peer Assessment:

In the two courses considered for this study, peer assessment and feedback were gathered using the tool developed by the Individual and Team Performance (ITP) lab at the University of Calgary (T O'Neill et al., 2015). The tool is hosted at www.ITPmetrics.com, an online software platform that offers free research-backed team-based assessment and is funded by the

Government of Canada (Thomas O'Neill & Maynard, 2018). The peer assessment tool — which is based on Ohland et al.'s (Ohland et al., 2012) Comprehensive Assessment of Team Member Effectiveness (T O'Neill et al., 2015) dimensions: communication, commitment, knowledge, skills and abilities, standards, and keeping the team on track — invites students to rate their peers on a five-point Likert scale and provide them with anonymous feedback on the five team member competencies that are associated with team effectiveness: commitment to the team's work, communicating with team members, having a strong foundation of knowledge, skills and abilities, emphasizing high standards, and keeping the team on track (Thomas O'Neill & Maynard, 2018). The tool provides each student with a peer rating average score that ranges from 0 to 5. The tool generates a report that presents students with anonymous feedback from their peers. Students then use this report in developing an action plan to improve on their strengths and weaknesses. A team debrief session is held during one of the lab sessions.

Project Ownership Scale:

Students' feelings of intellectual and emotional project ownership were measured using A 16-item Likert style survey was developed based on Hanauer et al. 2-year study (D. I. Hanauer et al., 2012). The survey consists of two subscales: the cognitive ownership subscale, a 10-item five-point scale that assess the degree to which students feel they have intellectual ownership over their work & the emotional ownership subscale, a 6-item scale that ask students to rate on a five point scale their strength of emotions towards their work. The survey has an internal reliability of $\alpha= 0.86$ for the cognitive ownership subscale and $\alpha= 0.85$ for the emotional ownership subscale. We have replaced the word 'lab' from the original scale with the word 'project' in our study to be more accurate in describing the subject of the assessment in this study which is students' ownership of their design project.

Triarchic Model of the Grit Scale:

Students' grit was also calculated using an 11-item scale developed by Datu et al. (Datu et al., 2017). The scale included three dimensions: perseverance of effort, consistency of interest and adaptability to situations. Adaptability to situations refers to an individual's ability to adapt to changing circumstances in life (Datu et al., 2017). Six of the 11 items were from Duckworth's Grit-S scale (A. L. Duckworth & Quinn, 2009) and the additional five items were measuring students adaptability to situations. Items were rated on 5-point Likert-type scale (1 = Not like me at all; 5 = Very much like me). In their validation study of the triarchic model of the grit scale, the internal reliability of the scale's dimensions were αs = .84, .84, .88 respectively.

Results

Table 1 presents descriptive statistics and intercorrelations among all study variables. Project ownership-content (POC) score had a significant negative small correlation with agreeableness $r = -.279$, $p < .05$, and a small positive correlation with neuroticism $r = .328$, $p < .05$. Students' project ownership-emotions (POE) level had a significant positive strong correlation with students' POC score , $r = .637$, $p < .01$. Adaptability to situations (ATS) score had a significant positive small correlation with openness $r = .234$, $p < .01$, extraversion $r = .233$, $p < .05$, and consistency of interests $r = .204$, $p < .05$, POC $r = .292$, $p < .01$, POE $r = .259$, $p < .05$; ATS also had a significant positive moderate correlation with grit $r = .378$, $p < .01$ and perseverance of effort $r = .448$, $p < .01$; moreover ATS had a negative small correlation with neuroticism $r = -.259$, $p < .01$.

Table 1 - MEANS, STANDARD DEVIATIONS AND BIVARIATE CORRELATIONS FOR PERSONALITY TRAITS, GRIT, PEER ASSESSMENT MARKS, FINAL MARKS, PROJECT OWNERSHIP, ADAPTABILITY TO SITUATIONS AND PERSISTENCE VARIABLES

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Openness | | | | | | | | | | | |
| ConscientiousnessP | -.016 | | | | | | | | | | |
| Extraversion | .450** | -.181 | | | | | | | | | |
| Agreeableness | .054 | .337** | -.475** | | | | | | | | |
| Neuroticism | .301** | -.361** | .398** | -.520** | | | | | | | |
| TMGS | .103 | .293* | .244* | .078 | -.306* | | | | | | |
| Peer Assessment | .108 | -.066 | .037 | -.032 | .175 | .118 | | | | | |
| Final Mark | .248* | .058 | .117 | -.049 | .232* | -.125 | .583** | | | | |
| POC | .140 | -.230 | -.002 | -.279* | .328** | -.241* | .014 | -.030 | | | |
| POE | .214 | -.041 | .016 | -.116 | .231 | -.225* | .025 | .153 | .637** | | |
| ATS | .234* | .173 | .212* | .147 | -.259** | .777* | .101 | -.084 | -.292** | -259* | |
| Number | 108 | 108 | 108 | 108 | 108 | 101 | 92 | 81 | 81 | 129 | 129 |
| Mean | 2.02 | 2.97 | 1.98 | 2.85 | 1.94 | 3.77 | 4.34 | 76.95 | 2.43 | 2.89 | 4.06 |
| Standard deviation | .630 | 1.12 | 1.20 | .744 | .942 | .522 | 11.57 | .589 | .758 | .595 | .562 |
| Cronbach's Alpha | - | - | - | - | - | - | - | .83 | .85 | .76 | .776 |

Next, we performed a set of four multiple regressions to examine the incremental validity of the triarchic model of grit scale (TMGS) in predicting students' final marks, peer assessment marks and project ownership content (POC) and emotions (POE) scores. The independent variables included in each of the four models were: openness to experience, conscientiousness, extraversion, agreeableness, neuroticism, and TMGS. We entered the Big Five personality traits in Step 1, the TGMS score was entered in Step 2. Cases with missing data where a student had dropped the course or elected not complete the initial personality assessment test, the TMGS or the project ownership questionnaire were excluded listwise from each analysis. Results of evaluation of assumptions led to the transformation of one dependent variable to reduce skewness, reduce the number of outliers, and improve the normality, linearity and homoscedasticity of residuals. Peer assessment marks were transformed using a reflection and log transformation.

As presented in table 2-3, the set of variables entered in the first block statistically significantly predicted students' POC score, R2 = .213, Adj. R2 = .153, F (5, 65) = 3.528, p = .007, students' final marks R2 = .286, Adj. R2 = .233, F (5, 67) = 5.373, p < .0005. The first block didn't statistically predict students' POE R2 = .105, F (5, 65) = 1.519, p = .196, nor did it predict the (reflect and logarithmic) students' peer assessment marks R2 = .054, F (5, 97) = 1.098, p = .366. In the first block, three personality traits added statistically significantly to predicting students' POC scores: Openness β = .274, t(71) = 2.079, p = .042, 95% CI [.011, .538]; extraversion β = -.168, t(71) = -2.275, p = .026, 95% CI [-.316, -.021]; and agreeableness β = -.305, t(71) = -2.168, p = .034, 95% CI [-.586, -.024]. As for the model predicting students final marks, three personality traits added significantly to the model: Openness β = 4.166, t(72) = 2.717, p = .008, 95% CI [1.105, 7.226]; conscientiousness β = 2.658, t(72) = 3.637, p = .001, 95% CI [1.199, 4.117]; and neuroticism β = 2.60, t(72) = 2.605, p = .011, 95% CI [.608, 4.593].

Adding the TMGS variable in the second block significantly increased the amount of variance explained for POC score ΔR2= .049, F(6, 64) = 3.796, p = .003, adj. R2 = .193, and students'

POE score however the regression model wasn't statistically significant ΔR2= .063, F(6, 64) = 2.153, p = 0.059, adj. R2 = .090. The amount of variance explained did not increase for students' peer assessment marks ΔR2= .025, F(6, 97) = 1.364, p = .237, nor for students final marks ΔR2= .001 F(6, 66) = 4.437, p = 0.001. In the second step, TMGS was a statistically significant positive predictor of students' POC scores β = -.030, t(70) = -2.062, p = .043, 95% CI [-.058, -.001], and POE scores β = -.043, t(70) = -2.208, p = .031, 95% CI [-.083, -.004].

Table 2 - Multiple regression coefficients for Big-Five personality traits & TMGS predicting students' POC & POE scores

| | POC | | | | | | POE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Step 1 | | | Step 2 | | | Step 1 | | | Step 2 | | |
| Predictor | B | SE B | β | B | SE B | β | B | SE B | β | B | SE B | β |
| Intercept | 3.143 | .531 | | 4.254 | .747 | | 2.848 | .730 | | 4.476 | 1.023 | |
| Openness | .274* | .132 | .285 | .280 | .129 | .291 | .292 | .181 | .235 | .300 | .176 | .242 |
| Conscientiousness | -.074 | .062 | -.137 | -.063 | .061 | -.118 | .002 | .085 | .004 | .018 | .083 | .026 |
| Extraversion | -.168* | .074 | -.334 | -.009 | .080 | -.197 | -.149* | .102 | -.230 | -.048 | .109 | -.073 |
| Agreeableness | -.305* | .141 | -.349 | -.289 | .137 | -.331 | -.198* | .193 | -.176 | -.174 | .188 | -.155 |
| Neuroticism | .073 | .084 | .124 | .018 | .086 | .031 | .120 | .116 | .158 | .040 | .118 | .052 |
| TMGS | - | - | - | -.056* | .014 | -.265 | - | - | - | -.043 | .020 | -.301 |
| $R^2$ | .213* | | | .262* | | | .105 | | | .168 | | |
| Adjusted $R^2$ | .153 | | | .193 | | | .036 | | | .090 | | |
| $\Delta R^2$ | - | | | .049* | | | - | | | .063* | | |

Table 3 Multiple regression coefficients for Big-Five personality Traits & TMGS predicting students' peer assessment & final marks

| | (Reflection and logarithmic) Peer Assessment | | | | | | Final Marks | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Step 1 | | | Step 2 | | | Step 1 | | | Step 2 | | |
| Predictor | B | SE B | β | B | SE B | β | B | SE B | β | B | SE B | β |
| Intercept | .288 | .096 | | .493 | .155 | | 61.483 | 5.439 | | 59.139 | 8.805 | |
| Openness | -.033 | .027 | -.171 | -.032 | .027 | -.167 | 4.166** | 1.533 | .350 | 4.17* | 1.543 | .350 |
| Conscientiousness | -.077 | .013 | -.064 | -.004 | .013 | -.035 | 2.658** | .731 | .428 | 2.61* | .751 | .420 |
| Extraversion | .015 | .015 | .158 | .024 | .016 | .250 | -1.281 | .841 | -.214 | -1.40 | .913 | -.234 |
| Agreeableness | .002 | .024 | .010 | .002 | .023 | .012 | -.774 | 1.273 | -.085 | -.77 | 1.282 | -.084 |
| Neuroticism | -.024 | .017 | -.196 | -.035 | .018 | -.285 | 2.600* | .998 | .341 | 2.72* | 1.064 | .356 |
| TMGS | - | - | - | -.056 | .034 | -.216 | - | - | - | .060 | .176 | .041 |
| $R^2$ | .064 | | | .099 | | | .286* | | | .287* | | |
| Adjusted $R^2$ | .000 | | | .024 | | | .233 | | | .223 | | |
| $\Delta R^2$ | - | | | .035 | | | | | - | .001 | | |

In our previous study (Authors, 2020b) although students' grit scores didn't predict their final marks, their perseverance of effort scores did predict their final marks in the course. To explore the predictive validity of each subdimension of the TMGS in predicting students' final marks, we conducted a hierarchal regression analysis to understand if any of the TMGS subdimensions are associated with students' final marks in the course. We entered the Big Five personality traits in Step 1, the subdimensions of the TGMS measure (TMGS-PE, TMGS-CI & ATS) were entered in Step 2. As shown in table 6, adding the subdimensions of the TGMS measure significantly increased the amount of variance explained by the Big-Five personality traits from 28% to 36%, ΔR2= .073, F(8, 64) = 4.491, p < .0005, adj. R2 = .280.

However, only the perseverance of effort subdimensions statistically significantly predicted students' final marks β = 3.569, t(72) = 2.621, p = .011, 95% CI [.849, 6.290].

table 4 - Multiple regression coefficients for big-five personality traits, TMGS-PE, TMGS-CI & ATS predicting students' final marks

| | Final Marks | | | | | |
|---|---|---|---|---|---|---|
| | Step 1 | | | Step 2 | | |
| Predictor | B | SE B | β | B | SE B | β |
| Intercept | 61.483 | 5.439 | | 57.526 | .8.547 | |
| Openness | 4.166* | 1.533 | .350 | 4.965* | 1.546 | .417 |
| Conscientiousness | 2.658* | .731 | .428 | 2.735* | .728 | -.440 |
| Extraversion | -1.281 | .841 | -.214 | -1.574 | .881 | -.263 |
| Agreeableness | -.744 | 1.273 | -.085 | -.718 | 1.244 | -.079 |
| Neuroticism | 2.60* | .998 | .341 | 2.549* | 1.026 | .334 |
| TMGS-PE | - | - | - | 3.569* | 1.362 | .306 |
| TMGS-CI | - | - | - | -.941 | 1.051 | -.100 |
| TMGS-ATS | - | - | - | -2.311 | 1.577 | -.163 |
| $R^2$ | .286* | | | .360* | | |
| Adjusted $R^2$ | .233 | | | .280 | | |
| $\Delta R^2$ | - | | | .073* | | |

Subsequent linear regression analysis was conducted to examine Datu et al. (2017) new subdimension of ATS in predicting students' learning outcomes in this learning environment. The regression established that ATS statistically significantly predicted project ownership-content R2 = .085, F(1, 78) = 7.260, p = .009, adj. R2 = .073; project ownership-emotions R2 = .067, F(1, 78) = 5.631, p = .02, adj. R2 = .055. ATS did not statistically predict peer assessment mark, F(1, 97) = .964, p = .329, adj. R2 = , nor did it predict final marks F(1, 87) = .616, p = .435.

To understand if there is a relationship between students' feelings of intellectual or emotional ownership on their peer assessment marks or final marks, A multiple regression analysis was conducted to predict students peer assessment marks from their project ownership-content and emotions scores. Results of evaluation of assumptions led to the transformation of one dependent variable – peer assessment marks - to reduce skewness, reduce the number of outliers, and improve the normality, linearity and homoscedasticity of residuals. A reflection and log transformation was used on students' peer assessment marks Project ownership-content and -emotions didn't statistically significantly predict (reflection and log of) students' peer assessment marks, F (2,55) = .017, p = .984, nor did it statistically significantly predict students' final marks F (2,54) = 1.493, p = .234.

## Discussion

The results of the study indicate that grit as a higher order construct composed of perseverance of effort, consistency of interests and adaptability to situations did not predict students' final marks nor their level of contribution to their team's project. However, only the perseverance of effort subdimension of the TMGS predicted students' final marks. These results confirm our findings in a previous study (Authors, 2020b) using Duckworth et al. (2009) Grit-S scale which found that grit as a higher order construct composed of perseverance of effort and consistency of interests had no association with students' final marks or the level of contribution each student provides in their team's project. When assessing Datu et al. (2017) new subdimension of the grit construct – adaptability to situations – we found that it has no association with student's academic success in this learning environment. These results suggest that only students' ability to persevere in the face of challenges for long-term goals allows them to succeed in design courses based on making projects. The results confirm Credé et al. (2017) argument that grit has a modest relationship with academic performance. Moreover, it provides evidence to Credé et al. (2017) hypothesis that grit might predict performance in military basic training or well-defined academic tasks but grit might not be a relevant predictor of performance in ill-defined tasks requiring creativity and abandoning unsuccessful strategies. Moreover, these results indicate that grit might also be a poor predictor of performance in socially situated tasks and projects.

The results of the study also indicate that students' Big-Five personality traits are related to students' development of intellectual ownership of their projects. Students' development of intellectual ownership of their projects was positively related to extraversion and agreeableness, and negatively associated with openness. These results suggest that students who are active, social, cooperative and tolerant were more likely to develop intellectual ownership of their design projects, while students who were imaginative, intellectually curious and behaviorally flexible were less likely to develop intellectual ownership of their design projects. An explanation for this result might be that the courses emphasize product over process as students are required to create a functioning prototype by the end of the course. This might be pushing students who rank high on openness to experience to feel less intellectual ownership over their projects.

The negative relationship between the personality trait of openness to experience and students' development of intellectual ownership of their projects can also be a result of the presence of different thinking processes embedded in design projects, with each process appealing to different students with different personalities. The projects that the students worked on were innovative and creative in nature as students created a product that solves their client's unique problem. What's unique about design, innovation and creativity projects is that they all have convergent thinking and divergent thinking phases (Du Preez & Louw, 2008; Goldschmidt, 2016; Chamorro-Premuzic & Reichenbacher, 2008). Dym et al. (Dym, Agogino, Eris, Frey, & Leifer, 2005) argued that design thinking is characterized as an iterative loop of divergent and convergent thinking (*p*. 104). Divergent thinking is concerned with exploring and developing concepts while convergent thinking aims to explore the knowledge domain and is often concerned with revealing facts (Khalaf, Balawi, Hitt, & Radaideh, 2013). Moreover, the pedagogical approach used in the course is similar to that of problem based learning, a pedagogical approach that provides students with a problem or a project to solve, guides students through an iterative process of divergent and convergent inquiry and decision making (Khalaf et al., 2013). The personality trait of Openness to experience is associated with divergent thinking, and it has no association with convergent thinking (Chamorro-Premuzic & Reichenbacher, 2008). In the course understudy students were required to develop concepts as well as develop prototypes, which means that they had to go through an iterative process of divergent and convergent thinking to make their designs a reality. Although Chamorro et al. (Chamorro-Premuzic & Reichenbacher, 2008) findings doesn't quite provide an explanation for the negative relationship between openness to experience and students' intellectual project ownership in the course under study as they didn't find any relationship between openness to experience and convergent thinking, it does provide guidance for future research to investigate the interaction between students' personality traits and the different phases of creative design projects.

An interesting result of the study is that grit as measured with the TMGS scale was positively related to students' development of intellectual ownership of their projects. However, among the TMGS subdimensions, only the adaptability to situations dimension of Datu et al.'s (2007) scale was a positive predictor of project ownership-content scores. This result indicates that students' ability to adapt to changes determines their ability to develop intellectual ownership of their project. Since engineering design is conducted with ambiguous goals and incomplete information that is usually completed or updated throughout the life of a project (Dym, 1999), students' ability to adapt to changes in different situations will determine the likelihood of their development of intellectual ownership of an engineering design project. This result suggests that engineering educators should place more emphasis on developing students' ability to adapt to changes as it will allow them to develop intellectual ownership of their engineering design projects and thus prepare them to be able to solve design and engineering problems in their future courses in engineering school and career as well as encourage them to pursue a career in engineering design. Moreover, as students' feel more responsible for their projects they are more engaged in the learning environment and feel personally connected to their projects (David I. Hanauer et al., 2016).

Another interesting result in the study was that neither intellectual nor emotional project ownership predicted students' academic performance in the course. This result can be explained by the fact that students' final marks in the course measures several elements of students' learning that include students' knowledge of design process as assessed in the final exam, students design and communication skills and progress in the course as assessed by the project mark which also factors each students' contribution to their team project, thus the course's final mark doesn't provide a separate assessment of a student's design skills or reflect their practice or identification with engineering design. Also, authentic assessment that relies on written communications have been criticized as considerable percentage of the amount of variance in scores can be attributed to written styles (Hathcoat, Penn, Barnes, & Comer, 2016). Moreover, although students' peer assessment represents an authentic assessment tool where students reflect on their peers and their own contribution to their projects, students might have been motivated to contribute to their team's project because they want to achieve a certain grade regardless of their intellectual or emotional ownership of the project.

## Conclusion

The main aim of the study was to assess the role that grit and project ownership play in predicting students' academic success and level of contribution in engineering design courses based on making projects. The study also aimed to explore the role of grit in predicting The study confirmed earlier findings (Authors, 2020b) that grit is not a relevant predictor of performance in learning environments that are socially situated and that require creativity and innovation even when grit is measured using a more up to date scale (Datu et al., 2017). The study also pointed to the positive relationship between the perseverance of effort subdimension of grit and academic success of students in the learning environment understudy. Moreover, the study pointed to the positive relationship between the personality traits of extraversion and agreeableness, and students' ability to adapt to changes and situations with students' development of intellectual ownership of their project. The results also point to the negative relationship between students' development of intellectual ownership of their project and the personality trait of openness to experience. The study has also provided more insight to the construct of project ownership in an academic makerspace setting. The findings indicate that students' development of intellectual or emotional ownership of their project were not related to any students' academic success nor to their level of contribution to their team's projects. However, an unexpected result that emerged from study was that adaptability to situations subdimension of grit was positively associated with students' development of intellectual and emotional ownership of their projects.

This study is limited by its' reliance on self-report questionnaires which might be susceptible to faking or social desirability bias especially when students are asked to assess their own competence (Datu et al., 2017). Second, the design that I followed in phase 2 limited me from investigating the impact of students' development of project ownership whether emotional or intellectual on the level of grit they would employ during their project. In designing the data collection tool in the second phase of the research I had to administer the grit measure at the beginning of the semester and assess students' feelings of project ownership at the end of the semester. First, Administering the data collection tools in two steps was necessary to ensure that the questionnaire isn't too long and motivate students to complete the questionnaires of the study as a questionnaire's length has a significant effect on the dropout rate (Mortel, 2008). Second, because the Grit-S scale originally developed by Duckworth (Ganassali, 2008) and of which the TGMS is developed is not suitable to be used for pre-test post-test assessment research, thus I wasn't able to re-administer the scale to measure students' grit level at the end of the study.

The implications of the study to educators planning to integrate making projects and activities to their curriculum should promote and help students develop traits of perseverance, organization, and diligence to help students succeed in the course. Educators should also promote traits of extraversion, agreeableness, and students' ability to adapt to effectively to changing circumstances in life to increase students' ability to develop intellectual ownership of their design projects. The results of the study also point to several research gaps including the need for empirical research to investigate the relationship between creativity and students' learning outcomes such as academic success or development project ownership in learning environments based on making settings. Also, more research is needed to understand which part of the design processes – divergent or convergent – does different of students with different personality traits enjoy and how educators can develop project ownership in engineering design projects. Moreover, there is an urgent need to develop authentic assessment methods of students' learning in learning environments that are based on making projects and activities.

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