Understanding Feelings of Inclusion in Making and Engineering

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Abstract

The maker movement is a growing social phenomenon that is being embraced in various fields, including education. There are many advantages to incorporating making into education, especially in engineering design, such as supporting real-life application of knowledge, multidisciplinary collaboration, problem-solving and teamwork. Elements that have not been looked at in the literature are the impacts of these making elements on students, more specifically on their feelings of inclusion in making and engineering environments. The extent of the impacts of making on project outcomes and teamwork in project-based learning engineering design courses are also contested. This thesis fills those research gaps by exploring students' feelings and behaviours in a university makerspace and cornerstone engineering design courses.

The general objectives are to study the effects of the makerspace as well as team dynamics and personality traits on student perception and behaviour in the Faculty of Engineering, specifically in cornerstone engineering design courses. This will be achieved by exploring factors that lead to feelings of inclusion in making and engineering, identify reasons students participate in these communities and exploring factors that influence team performance in a project-based engineering design course. Three studies are then conducted to meet these objectives.

The first study found that in both the making and engineering contexts, connecting with the identity, participation and distinctiveness were identified as themes that provide reasons for feeling or not feeling included. Sustained involvement was identified as being an important factor in leading to increased feelings of inclusion. The second study found a difference between men and women, where the adjusted project grade for male students can be in part explained by some personality traits, but no traits were found to be significant for female students. The average team conscientiousness was also found to be a predictor of the team project grade. The last study found that the course has an equalizing effect on feelings of inclusion for students in engineering. Making seems to have the same effect as engineering for male students; however, not for females. Adjusted project grade was also found to be a significant predictor of the change in scores for all students' feelings of inclusion in making and for the female students' feelings of inclusion in engineering.

Keywords: inclusion, maker movement, engineering identity, teamwork

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Glossary

Table 1. Glossary

Term	Definition
Inclusion	"The degree to which an [individual] perceives themselves as an esteemed member of the group through experiencing treatment that satisfies their needs for belongingness and uniqueness". (Shore et al., 2011, p. 1265)
Makerspace	A space for digital fabrication that allows people to develop creativity, innovation, problem-solving and technical skills by working on self-selected projects (Davis & Mason, 2017; Saorín et al., 2017; Taylor et al., 2016; Whitmer, 2016).
Cornerstone design course	A first-year course that typically uses project-based learning to teach students design and includes a real-life hands-on problem to be solved by a team of students, providing them with experiential learning that helps increase their creativity and design thinking. (Dym et al., 2005)
Grounded theory	Grounded theory method is a systematic, inductive and comparative approach for conducting inquiry for the purpose of constructing theory and encourages researchers' persistent interaction with their data. (Bryant & Charmaz, 2007)
Pearson's correlation	Statistical product-moment correlation to determine the strength and direction of a linear relationship between two continuous variables. (Lund Research, 2013)
Spearman's correlation	Statistical rank-order correlation to measure the strength and direction of a relationship between two continuous or ordinal variables. (Lund Research, 2013)
Kruskal-Wallis H test	A rank-based non-parametric statistical test to determine if there is a significant difference between two independent groups on a continuous or ordinal dependent variable. (Lund Research, 2013).
Linear regression	Assesses the linear relationship between two continuous variables and predict the value of the dependent variable based on the value of the independent variable. (Lund Research, 2013)
Multiple regression	Predicts a continuous dependent variable based on multiple independent variables, determines the overall fit of the model and the relative contribution of each of the predictors to the total variance. (Lund Research, 2013)

1. Chapter 1 - Introduction

The objective of this thesis is to explore inclusion in making and engineering communities, the factors that lead to feelings of inclusion and reasons for participation. The thesis also explores factors that influence team performance in an engineering project-based design course as well as the relationship between team performance and inclusion. Making elements have been introduced in engineering design projects at the University of Ottawa (also referred to as uOttawa) where students work together to fabricate and test prototypes. These projects are situated in client-centred, hands-on cornerstone courses in the MakerLab, a prototyping facility in the Centre for Entrepreneurship and Engineering Design (CEED) where this research takes place. This chapter outlines details about CEED and the courses, as well as the motivation for this research and its contribution to the field of study.

1.1. Centre for Entrepreneurship and Engineering Design

The University of Ottawa's Centre for Entrepreneurship and Engineering Design is composed of seven facilities. They include a makerspace with digital prototyping tools, a machine shop with traditional prototyping tools, and training centres for all types of equipment. Undergraduate students of all years and graduate students are able to use the spaces to gain knowledge and skills, as the spaces are open to all students in the university during the week. The makerspace is staffed with undergraduate students, graduate students and recent alumni and also open to the outside community on Sundays. All users can work on personal and school projects for free.

The uOttawa Richard L'Abbé Makerspace was launched in September 2014 in a small room that used to be an old computer lab in the Faculty of Engineering. It had a few pieces of technology, including some 3D printers, Handibots (hand-held CNC routers), hand tools and computers. The Makerspace doubled in size in 2015, and the Manufacturing Training Centre (MTC) and the MakerLab (a makerspace training and design course lab space) launched in 2016. All but one CEED space then moved into a new science, technology, engineering and math (STEM) building in 2018, where the Makerspace, MakerLab and most of the facilities at least doubled in size again and are prominently featured on the main floor. In this thesis, makerspaces at uOttawa refer to all these CEED facilities.

1.2. Engineering design courses

To address the need for cornerstone design courses in engineering curriculum and to take advantage of the clear link between engineering and the maker movement, uOttawa developed its first- and second-year engineering design courses around principles of project-based learning. The first-year engineering design course, called Engineering Design, is now mandatory for first-year mechanical, biomedical mechanical, chemical, electrical and civil engineering students. The second-year engineering design course, called Introduction to Product Development and Management for Engineers and Computer Scientists, is open to students in all departments of engineering as well as computer science students from different years. The focus of both courses is on client-centred design, where groups of students work on a specific client's problem or needs during one semester and deliver a final tangible prototype. Multidisciplinary and multi-year groups of engineering and computer science students are formed within the first two weeks of class. In the first week of class, students are required to do a Big Five personality test from ITP Metrics (O'Neill et al., 2018), which gives them a rating for each of the Big Five personality traits (John & Srivastava, 1999). With reflection on their personality, students pick their own teams in the first two weeks of the semester from students in the same lab section. They are encouraged to seek diverse types of people with complementary personalities and skills sets to form a team of four to six members. Their first deliverable then consists of creating and signing a team contract.

The lectures and the labs are the two main components of the courses. In the lectures, the students learn design methodologies, processes for product development, and time and project management. Students in the second-year course also learn about business models, economics and marketing. Students put these skills to use in their own semester-long project to meet the needs of a specific client. Within each section of the first-year course, teams of students work for the same client on the same project, which is usually different for each section of the course. In the second-year course, the students are given a list of projects for various clients and asked to choose their top three. The professors then distribute projects so as not to have more than two teams working on the same one. The theme for the first-year course changes almost every semester and is different between sections. The theme for the second-year course is always accessibility. This means students work on projects like wheelchair skis, portable wheelchair ramps and foot-controlled guitars. Clients are diverse, ranging from individuals to organizations like hospitals, and have different needs.

Each team meets their client a minimum of three times during the semester. The first-year course meetings are either in the classroom or lab, and the students in the second-year course meet their client wherever is most convenient for the client. The first meeting with the client, in the third week of the semester, is used to determine specific needs for the project. The teams then develop solution metrics and concepts before meeting the client a second time to get feedback. Next is the start of the prototype iteration cycle, where the students use the CEED facilities to make three or more prototypes to get to their final product. After the first prototype is completed, a third client meeting is held to receive more feedback on the product features and functionality. The client is then presented with the final product at the end of the semester at Design Day, a showcase featuring all the cornerstone engineering design teams.

The work is done mostly outside the classroom, with some lab time dedicated to working on the project. The rest of the labs are designed to teach students the necessary skills to be able to do their projects or to give them enough of an introduction that they can learn more by themselves if needed. Skills taught in the first-year course include Solidworks, Matlab, laser cutting and one lab that varies to teach something project specific. In the second-year course, students learn 3D printing, PCB design, mobile app development and how to use lathes and mills. In addition, both courses teach Arduino, soldering and sheet metal work. The labs for the second-year course are done with the specific goal of making parts for a small smartphone-controlled car that is assembled in one of the last labs. All labs take place in the MakerLab, which is a sister facility to the Makerspace and one of the CEED spaces.

Each lab has a teaching assistant (TA) and a project manager (PM) who are present every week. The TA is typically a graduate student, and the PM is typically an undergraduate student who has taken the course before. Both the TA and the PM act as guides and mentors to the groups as they go through their design process and learn the skills necessary to do so. Both sit together at the end of the semester and evaluate each student in their lab based on their contribution to the project over the semester. The students also evaluate their TA and PM at the end of the semester.

Each group does a peer and team assessment twice in the semester using a tool developed by the Individual and Team Performance (ITP) Lab at the University of Calgary, one of the ITP Metrics assessment tools (O'Neill et al., 2018). The first individual and team evaluation happens in the sixth week of the term, so the groups are able to receive feedback from their teammates and improve on their work before most of the heavy project work and prototyping happens. The first evaluation is also used by the professor, TA and PM to catch the groups that need extra help or an intervention to resolve group problems. The second evaluation happens at the end of the term and is used to weigh the final project grades based on the contributions from each member.

1.3. Motivation and statement of the problem and bias

CEED spaces have evolved and expanded over the last few years. The Richard L'Abbé Makerspace has expanded three times since its launch to a space triple in size in 2018 in a brand-new building. There were 1,800 unique visitors in the Makerspace in its 2019-2020 fiscal year. In addition, the two cornerstone engineering design courses are hosted in the MakerLab in the midst of these prototyping spaces. They started with 8 students in 2016 and included nearly 1,000 in the 2020-2021 academic year. They are based on prototyping and group work to solve a problem.

Given the amount of expansion of the CEED spaces and the increasing number of people using them, there is value in studying and understanding their effect on feelings of inclusion within the uOttawa Faculty of Engineering as well as the effect of these spaces on student design teams. Some people already feel included in this environment; others may feel more included after taking the course, while still others never feel included. The increasing number of teams also leads to a need for a better understanding of teamwork and team dynamics, particularly factors that can improve team performance and project results.

One of the research problems that arises from this situation is that the influence of makerspaces on inclusion in a university setting has not been widely studied. Research is also lacking on factors that may influence feelings of inclusion in making and in engineering. Therefore, this thesis explores feelings of inclusion in the making and engineering communities within the Faculty of Engineering at the University of Ottawa. It is also not clear what factors influence team dynamics and team performance; therefore, factors that have an impact on engineering design teamwork will be identified.

Significant research gaps exist in each area. Existing literature focuses on how to build and administer a makerspace because it is a relatively new structure and form of organization. Participant motivation and experience has only recently been an area of interest for researchers. Whyte (2017) outlined three studies in the first International Symposium on Academic Makerspaces in 2016 which focus on student experiences and another three from 2016 ASEE sessions. However, much of this work centers around demonstrating the benefits of these spaces (Radniecki & Klenke, 2017). More specifically, the community that surrounds a makerspace has been explained numerous times, although individual experiences and feelings of inclusion have only rarely been looked at with anecdotal evidence from staff members (Noel et al., 2016).

Makerspaces in university settings have been a more recent addition to the maker movement, and the effect of these spaces in engineering education is not yet clear. An engineering-specific definition of inclusion is given by Peters (2018, p. 6): “Inclusion is the extent to which an individual feels valued for who they are in terms of personal and professional background, experience and skills, and the extent to which an individual feels they belong or ‘fit’ in the engineering profession and in their organisation.” It is anecdotally understood that if a space like a makerspace is presented to people who already tend to design and build, like engineering students, it will cause these people to feel included there.

Gender is a popular topic in research on representation in engineering, given that engineering is known for its underrepresentation of women. Engineers Canada specifically has a goal of raising the percentage of newly licensed engineers who are women to 30% by 2030 (Engineers Canada, 2017). However, it is more difficult to evaluate the representation in engineering for other underrepresented groups, because statistics are scarce and tend to be only self-reported in voluntary surveys.

The literature outlines multiple contradictory views on how personality traits influence teamwork and task performance, and which specific traits have an influence. In the context of engineering design, the author is interested in understanding the various factors that have an impact on performance in a team and how feelings of inclusion might be affected.

The author recognizes that she has a large bias when exploring this field, since she identifies as a maker and has been working for CEED and involved with these specific makerspaces since 2015. She has been managing the MakerLab since 2017 and the Makerspace since 2019. She hopes this involvement has given her a better understanding of the environment, enabling her to gather more insights. It has also allowed her to easily connect with users of the spaces to gather data. However, her personal inclusion journey, team experiences and the hope that this makerspace is inclusive leads to opinions that may not always be objective.

1.4. Research contribution

Research on frameworks for psychological inclusion in a group or community is a new area with no consensus on a theoretical framework. Research in inclusion does not therefore explicitly exist in the context of making or engineering except for related topics such as subjective well-being and identity. Feelings of inclusion in a makerspace and the impact on its participants is a topic that has yet to be explored in depth; therefore, this is one of the main motivations for this research. In addition, inclusion in engineering as a by-product of engineering design courses that incorporate making is an area of interest and something that has not been explored previously. A conference paper has already been published on engineering students' baseline inclusion levels in making and engineering communities (Boudreau & Anis, 2019d). It should also be noted that most of the literature focuses on community and library makerspaces, looking at the wider population or at youth specifically. Therefore, exploring a makerspace in a university setting with students as well as community members adds value to the body of knowledge. The maker movement and makerspaces are relatively new, which means many aspects have been explored in only a limited way or not at all. Research has also generally been either qualitative (e.g., Rogers (2017), James (2020)) or quantitative (e.g., Koudenburg et al. (2017), Moilanen (2012)); therefore, this mixed-method study adds value and understanding to this topic.

Team dynamic studies offer varied and contradictory views on factors that influence teamwork and task performance. Since engineering design relies heavily on group work, it is interesting to know how a factor like personality will affect the outcome. A journal paper about teamwork, personality and their effects on project outcomes in engineering design has already resulted from this research (Boudreau & Anis, 2019a). In relation to the success of a team project, the level to which people feel included and are confident about their skills in engineering has not been previously studied. In engineering, inclusion is referred to only when discussing retention and graduation of students. In addition, the maker movement is described as open and inclusive, but there is very little detailed analysis of these aspects.

This research provides findings that can help understand the effects of a maker curriculum in engineering design with regards to inclusion and teamwork in a project-based learning environment. It also provides evidence-based recommendations for engineering educators to actively think about inclusion in their curriculum and possible effects on underrepresented groups. It presents findings that can be used to implement more inclusive environments and to create engineering design groups optimized for inclusion and performance.

1.5. Thesis structure

The general objectives of this thesis are to study the effects of the makerspace, as well as team dynamics and personality traits on student perception and behaviour in the Faculty of Engineering, specifically in cornerstone engineering design courses. Chapter 2 presents a review of the literature on theoretical frameworks for inclusion, making identity and engineering identity. The chapter also touches on the maker movement, engineering education, project-based learning, personality factors and teamwork. The research in this thesis is then divided into three sections: the role of makerspaces in inclusivity in engineering (Chapter 3), the effect of personality traits on team dynamics and project outcomes in engineering design (Chapter 4) and the effect of personality traits and project-based learning on feelings of inclusion in engineering (Chapter 5). Chapter 3 outlines factors that may influence the levels of students' feelings of inclusion in making and engineering and subjective reasons for feelings of inclusion or exclusion in these two communities. Chapter 4 outlines individual and group factors that influence team performance in a project-based learning environment. Chapter 5 builds on the research presented in chapters 3 and 4 by exploring whether personality traits and individual success influence students' feelings of inclusion in a project-based design course. Chapter 6 is a summary of all research and the findings and implications, in addition to avenues for future work.

2. Chapter 2 - Literature Review

To situate the research context, guide the research design and ultimately be able to answer the research questions, the literature outlined in this chapter was reviewed. Individual feelings of inclusion in the context of making and engineering, the factors that influence these feelings and whether the introduction of making activities has any effect on these feelings of inclusion are the subject of interest. Therefore, inclusion frameworks, making and engineering identity, the maker movement, engineering design and project-based learning are reviewed. Factors that influence team performance and individual performance within teams are also of interest, because understanding these factors would help instructors form more productive and better-performing teams and understand how each member contributes. Thus, literature on personality traits, diversity and team dynamics is also reviewed.

2.1. Inclusion

Inclusion has become a growing part of the organizational literature in the past two decades; however, it is still a relatively new concept for which there is no consensus on construct or theoretical framework (Cordier et al., 2017; Shore et al., 2011), even though humans are highly adapted for group living (Brewer, 1991). It is used to demonstrate the importance of engagement and participation because social inclusion can have a positive impact on individuals, groups and communities (Cordier et al., 2017).

Inclusion can be constructed from psychological needs for well-being in group contexts. A few different theories explain these needs for inclusion. Linking group membership to individual functioning is an important area that Brewer (1991) addresses with her optimal distinctiveness theory, since previous theories centred on the "self" do not explain collective behaviour or why individuals risk themselves for the benefit of a group. She explains that social identities are separate from a personal identity and are context dependent. Optimal distinctiveness theory is defined by the fact that individuals look for a balance of validation and similarity to others (belongingness) as well as uniqueness and individuation within a group from which their social identity is defined. This group must also be different from others to keep the loyalty of individuals. She states, "Group identities allow us to be the same and different at the same time" (1991, p. 477). The model shows optimal distinctiveness as the equilibrium between assimilation and differentiation in a group. Deci & Ryan also present a perspective on the "self." In their view, the self is "a set of motivational processes with a variety of assimilatory and regulatory functions" (1991, p. 238). This self-determination theory is a framework to differentiate intentional actions that are internally motivated and self-determined from actions that are not. Intrinsic motivation is characterized by four approaches: intrinsically motivated behaviours can occur in the absence of any apparent external reward, they are undertaken by a person out of interest, they are based on innate psychological needs, and intrinsically interesting activities are optimally challenging. Self-determination theory suggests that humans have fundamental psychological needs, namely, relatedness, autonomy (self-determination) and competence. Deci & Ryan attempt to explain the motivational processes necessary to achieve these needs, including personal satisfaction within a group context.

These two psychological need theories have led to the development of inclusion definitions and frameworks. Shore et al. (2011, p. 1265) use Brewer's optimal distinctiveness theory to define inclusion as "the degree to which an [individual] perceives themselves as an esteemed member of the group through experiencing treatment that satisfies their needs for belongingness and uniqueness." The inclusion framework developed by Shore et al. (2011) is based on the concept that when a unique individual is an accepted member by the group and the group values the unique characteristic, the individual feels included.

Many other scholars have also reasoned and empirically shown that a sense of belonging and a sense of individual uniqueness do not negatively affect each other (Jansen et al., 2014). Jansen et al. (2014) include self-determination theory when they refine the idea of valuing uniqueness of the previously mentioned framework. They suggest that the relatedness need from self-determination theory can be seen as equivalent to belongingness from optimal distinctiveness theory, the desire to feel connected to others. They also posit that authenticity (or autonomy) from self-determination theory resembles uniqueness in optimal distinctiveness theory, except that group members can be similar while being authentic, the perception of being encouraged to be true to oneself (Jansen et al., 2014). Their inclusion concept uses the broader authenticity need, divided into room for authenticity and value in authenticity, as well as the need to belong, divided into group membership and group affection. In conjunction with social identification concepts, which refer to the perception of the extent an individual is included based on cues by the group, they developed and validated a 16-question survey on a 5-point Likert scale to measure perceptions of inclusion.

In their examination of psychological need constructs, Sheldon and Bettencourt (2002) measure five group-related constructs from both optimal distinctiveness theory and self-determination theory: group inclusion, personal distinctiveness, group distinctiveness, personal autonomy and interpersonal relatedness. They use the constructs to develop and validate a 15-question survey on a 5-point scale used to measure subjective well-being and group inclusion.

2.2. Maker movement, maker culture and identity

The maker movement is a social phenomenon that evolved from the do-it-yourself (DIY) movement in the late 1960s with the emergence of information and knowledge-sharing platforms accessible via the internet and digital fabrication technologies (Collier & Wayment, 2018; Weiner et al., 2017). Maker Faires and community workshops (i.e., makerspaces) have been established and have proliferated rapidly as part of the maker movement (Jalan, 2018; Weiner et al., 2017). The maker movement has been described by Halverson & Sheridan (2014, p. 496) as three components: "*making* as a set of activities, *makerspaces* as communities of practice, and *makers* as identities". Makerspaces have been defined in various ways and can include assorted characteristics and features. The terminology also varies for similar types of spaces that essentially have the same function, including co-working spaces, innovation labs, media labs, fablabs, hacklabs and hackerspaces (Saorín et al., 2017; Taylor et al., 2016). In many cases, a makerspace is described as a space for digital fabrication that allows people to develop creativity, innovation, problem-solving and technical skills by working on self-selected projects (Davis & Mason, 2017; Saorín et al., 2017; Taylor et al., 2016; Whitmer, 2016). Makerspaces offer training and access to shared tools, usually for a small fee (Farritor, 2017; Han et al., 2017; Taylor et al., 2016). An important characteristic is also the community of learning and collaboration that accompanies the spaces, which is a core value of the maker culture (Davis & Mason, 2017; Farritor, 2017; Han et al., 2017; Martin, 2015). In addition, these spaces attract people who are passionate about making and identify with the maker culture (Farritor, 2017; Martin, 2015).

Makerspaces are generally informal spaces that can be located in a community setting or educational institution (Han et al., 2017; Taylor et al., 2016), but they exist in many different types of places. There are public and private spaces, including spaces in libraries, in grade schools and in academic engineering and arts schools. They may have slightly different characteristics but are all tied by the maker culture of learning and tinkering in shared spaces.

Makerspaces provide a lot of value for their members and their surrounding community (Taylor et al., 2016). They permit people to fail in a safe environment where they have the creative freedom to try again and seek expert help when needed (Hughes, 2017; Smay & Walker, 2015). The maker culture embedded in the spaces and their members includes characteristics of "making" (building, modifying and designing) and of "makers" (problem-solving, discovering, collaborating and learning) (Martin, 2015). This culture defines makerspaces as more than simply collections of tools by creating a community of learning and shared space that promotes principles like inquiry, play, innovation, critical thinking and personalized learning (Hughes, 2017; Taylor et al., 2016). The internet now has the ability to spread knowledge and, in combination with the availability of physical tools, is a pillar of the maker culture (Holm, 2015). Dougherty (2012) explains that learning new skills and creating enhances people's lives. He also states that the maker movement is built from the interconnectedness of people who mix together and extend conversations and common enthusiasm about tinkering. Hands-on learning is also facilitated in makerspaces, helping users to build confidence while developing interdisciplinary thinking and teamwork skills (Clauson & Sheth, 2017; Whitmer, 2016). Another advantage of the maker culture (or maker movement) is its emphasis on learning, teaching and empowerment through self-directed projects (Tanenbaum et al., 2013).

Maker identity represents the typical characteristics of the people who integrate themselves into the maker culture. These characteristics could be developed through participation in the makerspace or could be the source of attraction to the spaces (Whitmer, 2016). An identity can be "articulated as patterns of behavior that occur over longer periods of time" (Davis & Mason, 2017, p. 178); therefore, identity is not defined from one behaviour. Makerspaces have the ability to promote not only community identity awareness but also personal identities and digital literacy through the tools available (Hughes, 2017). Identities can be shaped through contact with maker tools and spaces and developed in such a way that individuals feel confident, worthy and cooperative (Hughes, 2017). In specific situations where an individual could have lost their previous identity in their social circle (e.g., retirement), a makerspace can offer a judgment-free space that is open to collaboration and networking to integrate into a new identity (Taylor et al., 2016). The maker movement is characterized by a maker mindset that comprises values, beliefs and dispositions common to the community — in other words, the maker mindset is indicative of the maker identity (Martin, 2015).

In their study on factors that contribute to the formation of a making identity with 11 self-identified young makers in the US, Weiner et al. (2017) identify three categories. The first is relational identity, where a maker is invested in a meaningful personal connection and is introduced to making through the relationship. The second is material discourse identity, where interactions with inanimate objects can lead to personal characteristics like patience or resilience. The third is preferential identity, where makers have unexplained interests or predispositions. Weiner et al. find that their participants did not emphasize the need for large facilities, that relationships and support from others can be transformative and that educators could take advantage of the self-directed learning that occurs naturally in makerspaces.

DIY motivations have also been found to include the desire to create, a lack of available products, a maker identity and enjoyment in the DIY community (Collier & Wayment, 2018; Jalan, 2018). The needs of the participants have been indicated as need for uniqueness, self-expression, sense of empowerment, perceived success and sense of self-improvement (Collier & Wayment, 2018).

2.3. Makerspaces and inclusivity

Given that the community of learning, collaboration and support is a core value of maker culture (Whyte, 2017), inclusivity could also appear to be a characteristic of makerspaces. The elements of group inclusion that consist of perceptions of belonging and authenticity (Jansen et al., 2014) are naturally present in a maker community as described here. Makerspaces can reach a wide audience, including those who are usually left out because of economic and social inequalities (Hughes, 2017; Niaros et al., 2017; Taylor et al., 2016).

Maker communities respond to the unique characteristics of their environment and allow people to take an active role: “community within these spaces is often one of the most valuable resources they have” (Taylor et al., 2016, p. 1416). In fact, the social aspect (including events and meeting people) and learning have been found to be top interests for participants (Moilanen, 2012). People from different communities are invited to learn and participate in maker environments because of the democratic nature of science (Honma, 2017). Design as an engineering pedagogical method is also open to different types of learners in a makerspace (Talley et al., 2017). This community offers collective value in the sharing of knowledge, tools, ideas and innovation to any participant (Liotard, 2017; Niaros et al., 2017). This innovation is also used for citizen engagement and empowering individuals (Halbinger, 2018). The attitude of sharing and openness present in these spaces leads to many open-source projects that encourage even more participation from the greater community (Bosqué, 2016; Holm, 2015).

Maker projects have the ability to empower makers through social projects, such as the creation of assistive technologies (Taylor et al., 2016). Projects that include culturally meaningful curriculum or relate to meaningful personal or community problems are empowering (Talley et al., 2017). Taking part in the maker movement can open up participants to an inclusive community of collaborators and like-minded people (Honma, 2017). These people are connected by a common passion. As a result, many fields that typically don’t interact, like crafts and engineering, now belong together (Dougherty, 2012). Some studies have found that making can provide satisfaction and social support, improve well-being and reduce stress (Collier & Wayment, 2018).

Since the maker movement has been embraced by educational communities in the fields of science and engineering, it seems reasonable that the demographics found in each are similar. Holbert (2016) explains that science and engineering are dominated by white men, with only 15% women and 10% Black and Hispanic people in the US workforce in science and engineering fields; these percentages correspond with the 2014 Maker Faire in San Francisco, where 70% of attendees were men and 97% of attendees had college degrees. Peters (2018) also shows that 15.8% of engineering undergraduates are women in the United Kingdom. The University of Ottawa reported 18% of those who graduated from engineering in 2014 were women (University of Ottawa, 2015). Of the 2,485 students who responded to an Engineers Canada survey of final-year engineering students in 2017, 28% were women and 26% had an ethnic minority background (Engineers

Canada, 2017). In a report addressing the need for an inclusive education environment in engineering, Peters (2018) outlines that only 57.1% of Black, Asian and minority ethnic (BAME) students received a degree with a high honours classification, in comparison with 73.2% of white students in the U.K. in 2012–13. She also explains that white men are more likely to choose to work in engineering than women and BAME graduates.

Moilanen (2012) conducted a longitudinal study of hakerspace communities around the world to provide information about values, interests and motivations of members and to define the meaning of a hackerspace. He found that a typical member was a 27- to 31-year-old man with a college level or higher education. He states that "communities are still 'man caves', but the amount of women in hacking seems to be rising at least through the hackerspace movement" (Moilanen, 2012, p. 107). Holm (2015) argues that despite the majority of participants being male, other aspects like career, industry and educational background provide important elements of diversity. He also points out that makerspaces are built around tools as opposed to being built around a product or specific activity, and so the community is full of diverse knowledge. In a project to encourage participation of underrepresented communities in maker activities, Holbert (2016) found that explicitly framed activities can be leveraged to increase diversity in makerspaces by attracting and including specific groups. Noel, Murphy and Jariwala (2016) from the Invention Studio at Georgia Tech also outline four strategies, like tours and group events, which can help to reduce barriers to entry and promote inclusion.

Although participants in maker culture and makerspaces have largely been white, college-educated men, efforts to attract more diverse groups of people into maker communities is a reported priority (Blikstein, 2018; Halverson & Sheridan, 2014). Making in informal learning settings like libraries or museums, encouraging personal identities to be integrated in making activities and intentional outreach activities are examples of strategies to diversify participants (Halverson & Sheridan, 2014; Noel et al., 2016). Despite the diversity challenges, makerspaces possess collaborative, inviting and inclusive traits and this is how it can be a great addition to engineering education. Making engineering education more inclusive would give all students the chance to achieve their potential, help enhance the quality of engineers and lead to better engineering solutions for the world. It is therefore important to teach inclusion and diversity, encourage an overall inclusive environment with respect and understanding, and consider how diversity might affect engineers in practice (Peters, 2018).

2.4. Engineering identity and retention

The literature in engineering relating to group belonging refers to engineering identity and is usually paired with retention strategies. So far, engineering identity research has not clearly expressed the relationship between theoretical constructs and engineering identity (Patrick & Borrego, 2016). Engineering identity is defined in many ways, but most research presents it first as a profession and characterized by what someone does (Choe & Borrego, 2019; Friedensen et al., 2018; Patrick & Borrego, 2016). Factors included in engineering identity can include competence in technology adoption, scientific thinking and professional knowledge (Friedensen et al., 2018). Friedensen et al. (2018) and Choe & Borrego (2019), for example, both use a framework that includes recognition, performance/competence and interest and that incorporates the ability to perform engineering work and the need to be recognized as engineers. Identity is also described as double-sided, with engineers positioning themselves as engineers and being positioned as such by others (Stevens et al., 2008).

Research has shown that students choose engineering for very different reasons, including a desire to become an innovator or help people, and not all aim to be professional engineers (Stevens et al., 2008). Therefore, students identify engineering with many different characteristics, including identifying with the application of math and science, solving problems and being technically competent and confident (Friedensen et al., 2018). This identity is presented generally as a single discipline; however, culture has been shown to vary in different engineering fields and therefore identity development could also vary. Friedensen et al. (2018) show how a department might construct a definition of its ideal engineer and how it trains its students to embody the ideal.

Friedensen et al. (2018) explain that not many other contributing factors to engineering identity have been researched and that cultural factors have been paid very little attention. They emphasize that personal and social identities merge with the engineering identity, and this can lead to difficulties for underrepresented groups, where these identities may be conflicting. They suggest considering ways to make more connections between engineering and social identities and incorporating real-world contexts to help students make meaningful connections to their education. Patrick & Borrego (2016) also caution engineering educators to be aware of the intersectionality of multiple identities and that identity is more complex than what is currently presented in the engineering identity literature. They also present multiple studies that have found gender to be a significant factor in engineering identity studies but state that more work is needed in true intersectionality rather than using gender as a dichotomous factor.

Developing an engineering identity has been found to have an effect on undergraduate persistence, retention and teamwork (Friedensen et al., 2018). Likewise, a strong engineering identity has also been shown to correlate with academic motivation and persistence in engineering undergraduates and graduates (Choe & Borrego, 2019; Patrick & Borrego, 2016). Stevens et al. (2008) support this by recommending that engineering programs ensure that students develop a strong identification with engineering in the early years to increase retention in the program. When people identify with engineering and feel included in the culture, it boosts performance, motivation and commitment (Peters, 2018). However, white men feel the culture is more inclusive than women, who in turn feel it is more inclusive than engineers from minority ethnic backgrounds (Peters, 2018).

2.5. Engineering education, project-based learning and makerspace integration

Engineering education has the goal of graduating people who have the skills that industry is looking for, who can define and solve a problem, who can design and who have complex design thinking skills (Blikstein, 2018; Dym et al., 2005; Saorín et al., 2017). Creativity, invention and innovation have also been identified as indispensable qualities for engineering (Talley et al., 2017). Before 1990, engineering graduates were often perceived by both industry and academia as having trouble making the jump from theoretical to practical work as they entered the workforce due to their lack of practice with the design process (Dym et al., 2005). Final-year capstone design courses and, later, first-year cornerstone design courses were created to respond to this problem (Dym et al., 2005). These courses typically use project-based learning to teach students design and include a real-life hands-on problem to be solved by a team of students, providing them with experiential learning that helps increase their creativity and design thinking (Dym et al., 2005).

Blikstein (2018) explains how the integration of makerspaces into school settings has become more popular in the past 5 to 10 years, encouraged by certain societal trends and strong research infrastructure. First, the business world and governments are now looking for people with critical thinking, problem-solving, creativity, design and communication skills, resulting in a greater emphasis on engineering and design in K-12 education. For example, Ontario lists all these skills in their new 2020 math curriculum for Grades 1-8 (Ontario Ministry of Education, n.d.). Second, countries wish to develop more knowledge- and innovation-based economies, something that necessitates radical educational change to achieve innovative workforces. Next is the rapid growth of the maker movement, from Fablabs in 2002, Make Magazine in 2005 and Maker Faire in 2006, in conjunction with the idea of teaching coding to children. Fourth is the new, low-cost fabrication tools, technologies and self-sustaining online communities that have become available in the marketplace. The last trend is the work published about interactions in lessons developed specifically for children as well as the effect and impact of the new technologies on learning. Blikstein concludes: “Digital fabrication and ‘making’ could be new and major chapter in a process of bringing powerful ideas, literacies, and expressive tools to children, instead of merely providing technical training for the job market” (Blikstein, 2018, p. 434). Dougherty (Honey & Kanter, 2013, Chapter 1) agrees that the maker movement has the opportunity to transform education to allow students to grow socially and personally. He has many suggestions for bringing the maker movement to education; among them are “to create a context that develops the maker mindset, a growth mindset that encourages students to believe they can learn to do anything; to design and develop makerspaces in a variety of community contexts that serve a diverse group of learners who do not share the same resources; to develop educational contexts that link the practice of making to formal concepts and theory” (Honey & Kanter, 2013, p. 10).

Makerspaces are ideally suited to an engineering educational setting, given that “engineering practice is not simply a problem-solving process and specialized knowledge. It is the complex, thoughtful and intentional integration of these towards some meaningful end” (Sheppard et al., 2006, p. 435). As Peters (2018, p. 3) states, “Real-world projects, scenarios and case studies offer an authentic experience that prepares students to face the engineering challenges of the 21st century. They also provide a context to develop the skills that will empower engineering students to be more self-aware, better communicators and/or managers.” By fostering collaboration, innovation and entrepreneurship across the entire engineering curriculum, makerspaces in these settings can also contribute to student retention (Holm, 2015).

The maker movement is based heavily on experiential learning, or "learning by doing" (Talley et al., 2017). It is "a growing movement of hobbyists, tinkerers, engineers, hackers, and artists committed to creatively designing and building material objects for both playful and useful ends" (Martin, 2015, p. 30). Makerspaces facilitate hands-on learning and the incorporation of project-based learning into engineering curriculum in universities and in STEM education in K-12 (primary and secondary school) (Smay & Walker, 2015; Talley et al., 2017). Dougherty (2012, p. 12) also agrees that the "contemporary science of the brain confirms the importance of tactical engagement and of using our hands in the learning process." Makerspaces integrate well into the engineering design mindset, something that has led to successful implementations of makerspaces within the university community, as Talley et al. (2017, p. 2) state: "A close relationship exists between the engineering design process and making." They explain how makerspaces are relevant to engineering education based on the following factors: learning is an active and constructive process, construction of knowledge happens well through the building and sharing of objects, education should be experiential and connected to real-world situations, and design is an engineering pedagogical method that is accessible to many types of learners (Talley et al., 2017). These ideas are seconded by Martin (2015), who highlights three aspects of the maker movement that are beneficial to engineering education: digital tools encourage easy making; community infrastructure provides for member engagement, sharing and collaborative problem-solving; and the maker mindset describes participation as playful, asset- and growth-oriented, failure-positive and collaborative. Saorín et al. (2017) also support makerspace implementation in education because it serves to bridge gaps between science, technology and arts and promotes increased creativity in interdisciplinary settings.

2.6. Collaborative learning and teamwork

Institutions want to graduate engineers who can design and who have complex design thinking skills, including the ability to think and communicate as part of a team (Dym et al., 2005). Project-based learning is known to enhance student motivation and retention by providing hands-on experience solving practical problems while working in a team (Dym et al., 2005). It is a common educational method to apply knowledge to solving an open-ended problem (Vaz et al., 2013). Gomez Puente, van Eijck & Jochems (2013), in their literature review of design-based learning approaches, identify key characteristics of design-based learning. They explain that design tasks are often done collaboratively in a community of practice in contextualized situations where peers work together, communicate ideas and use engineering terminology. Teamwork and collaborative learning are also shown to be the basis for project-based learning. The authors outline projects that are the most relevant to project-based learning as open-ended, authentic, hands-on, real-life and multidisciplinary design projects. Authentic and open-ended design projects offer the opportunity to develop reasoning and domain-specific knowledge and to enhance the inquiry process. Another characteristic of design-based learning is that students are supervised and coached during their design process and project implementation to scaffold their learning and enhance their understanding.

Project-based learning work is a prime example of an out-of-class collaborative learning activity that has been confirmed as working particularly well for engineering design courses and that presents benefits like helping students to develop alternative methods of approaching problems and improving social and communication skills and self-confidence (Felder & Brent, 1994; Gomez Puente et al., 2013). Collaborative learning can be broadly defined as “a situation in which particular forms of interaction among people are expected to occur, which would trigger learning mechanisms” (Dillenbourg, 1999, p. 5). Collaborative learning is where students work in teams to accomplish a common goal while the following elements are present: positive interdependence, individual accountability, face-to-face promotive interaction, appropriate use of collaborative skills and group processing (Felder & Brent, 1994). In comparison with traditional lecture-centred learning, students participating in cooperative approaches demonstrate higher academic achievement, greater persistence and critical thinking skills, deeper understanding of material, and more positive and supportive relationships with peers (Clinebell & Stecher, 2003; Johnson & Johnson, 2006).

Engineers will always be faced with working in a team, most likely a diverse one, to accomplish their work (Brewer & Mendelson, 2003). Teamwork skills are a top priority for employers, which is another reason they should be taught explicitly (Clinebell & Stecher, 2003; Dym et al., 2005; Gomez Puente et al., 2013; Oakley et al., 2004). Some students who are interested in engineering are trained in teamwork before entering university (Gero & Danino, 2016). Teams enable multiple perspectives, experiences and a broad skill set for projects (Hacker, 2000; Peeters et al., 2006). However, simply putting students into groups does not generate collaborative learning; structuring them to be cooperative is necessary for this learning to happen (Felder & Brent, 1994; Johnson & Johnson, 2006). This structure must include parameters for the form of instructions to students, the physical setting and other institutional circumstances where a type of social contract can specify the types of interactions that can occur (Dillenbourg, 1999).

Ideally, in collaborative learning, people with a high degree of interdependence work together to complete a common goal (Hacker, 2000). Collaborative learning can greatly enhance a student's experience; however, if a team is dysfunctional, it can lead to a negative experience. For example, members who do not participate, causing an extra burden on the rest of the team members, will trigger low team morale and reduced cooperation (Clinebell & Stecher, 2003). Therefore, teamwork skills such as project and time management, conflict resolution and communication skills should be taught to student groups to help them have the best experience possible (Gomez Puente et al., 2013; Oakley et al., 2004). In a statement that encapsulates much of this research, Oakley et al. write, "With a group, the whole is often equal to or less than the sum of its parts; with a team, the whole is always greater" (2004, p. 13).

Team performance models include individual, group and environmental factors. Organizations often do team training to address individual factors, like experiences and skills, and improve interpersonal relationships with conflict management (Hacker, 2000; Hua, 2013). A few methods have been outlined for how and when to teach teamwork skills. Although there are differing theories, many agree that teams should be allowed to try, fail and learn from their experience as well as be offered guidance and training when problems come up (Felder & Brent, 1994; Gomez Puente et al., 2013; Oakley et al., 2004).

2.7. Personality and diversity

Diversity is a characteristic of a social grouping that reflects actual or perceived differences between people in the group (Homan et al., 2008). Peters (2018, p. 6) defines diversity this way: "Diversity considers similarities and differences in terms of age, ethnicity, disability, gender and religion, as well as less visible differences such as sexual orientation, disability, religion, educational background, personality type, nationality etc.” Diverse teams are seen as an important way to encourage innovation and creativity, as well as diversity more generally (Dym et al., 2005; Hua, 2013; Shen et al., 2007), and contain diverse information and knowledge (Homan et al., 2008). Since it is almost impossible to create a homogenous team (Homan et al., 2008), many studies have been conducted on personality types and the advantages that diversity in teams has for functionality and performance. Individual differences have an effect on team effectiveness and group processes (Clinebell & Stecher, 2003). Within the study of group diversity and ways it can enhance work processes that promote value in diversity, researchers are now searching for ways to integrate diverse individuals into organizations (Shore et al., 2011).

One of the personality indicators is the Big Five factor model, which can “represent diverse systems of personality, description in a common framework” (John & Srivastava, 1999, p. 103). The five factors in the Revised NEO Personality Inventory (NEO PI-R), or OCEAN, are openness, conscientiousness, extraversion, agreeableness and neuroticism (Clinebell & Stecher, 2003; John & Srivastava, 1999). This variable-centred approach focuses on dimensions (or traits) in a population (Chiang, 2011). Each factor is characterized by various dimensions of personalities. Openness refers to curiosity, active imagination, aesthetic sensitivity and independent-mindedness; conscientiousness is self-discipline, determination, a will to achieve, being orderly and being responsible; extraversion refers to being talkative, sociable, assertive and energetic; agreeableness is the tendency to be cooperative, altruistic and trustful; and neuroticism is the tendency to experience negative affect, to not be calm and to be neurotic (Clinebell & Stecher, 2003; John & Srivastava, 1999; Peeters et al., 2006). A person can range from high to low on a scale for each factor. George and Jones (2012) argue that no personality profile is necessarily better than another, as different factors are suited to different kinds of tasks, and point out positive aspects of low and high degrees of a factor. Some factors have been hypothesized to have specific effects on team performance. For example, high conscientiousness is believed to have a relationship to good performance, high neuroticism may lead to proficiency in critical thinking, and low agreeableness may be a sign of a good drill sergeant (George & Jones, 2012). Since this theory has been proved multiple times in academia, numerous studies have used it to determine the influence of personality on team effectiveness (Chiang, 2011; McCrae & Costa, 2003; Sherif, 2018).

Homan et al. (2008) outline that other types of diversity, like demographically diverse teams, might lead to inter-group bias but have also found to be positively related to group performance in other studies. Clinebell and Stecher (2003) explain that these different combination of factors and personalities put together may enhance or detract from group performance but that group performance should ultimately be facilitated by diverse personality types, since they can provide a balanced approach overall. But although diverse personalities are needed, they can also lead to conflict and different expectations of the team process. This idea is supported by Hua (2013) and Chiang (2011) in their dissertations. Cronin & Weingart (2007) present the view that diversity will increase the likelihood of the miscommunication and misinterpretations of needs and tasks to be accomplished by the team and therefore is likely to create conflict. When team members are not aware of personality-type information and its use in a team setting, there also tends to be more role conflict in the group (Clinebell & Stecher, 2003). Equally, Clinebell and Stecher (2003, p. 378) state that "awareness of differences was actively used by students to promote team functioning." In this case, it is important to know how different personality traits can influence the outcome of a team project. However, an opposite view holds that conflict will generate creativity, spark innovation and force team processes to improve (Hua, 2013). Finally, diversity is also seen as a business necessity: having employees who are comfortable with diverse cultures provides a broad range of perspectives and experiences (Busch-Vishniac & Jarosz, 2004; Ostafichuck & Naylor, 2017).

2.8. Team formation and peer evaluation

There are many ways design teams can be formed, and the literature varies on which give the best results. The main difference is between teams that are self-selected and instructor-assigned and, if they are assigned, the factors that the decisions are based upon. For collaborative learning groups, research supports the formation of teams that are generally instructor-assigned and have three to four members (Clinebell & Stecher, 2003; Felder & Brent, 1994; Oakley et al., 2004). Felder and Brent (1994) and Oakley and al. (2004) argue that teams must also be formed with people of different ability levels and not have people who are in minority groups outnumbered. The reason for these choices is that students who are further along in their understandings of course content benefit from teaching it to others because it helps them to consolidate ideas; students who are still grappling with the complexity of ideas can benefit from receiving explicit access to their peer's strategies. Teams can also be formed with more explicit attention paid to different personalities and roles within teams (Shen et al., 2007). The methods of doing this include the Myers-Briggs Type Indicator (MBTI) and the Big Five personality type indicators. For example, Shen, Prior, White and Karamanoglu (2007) use the Keirsey Temperament Sorter, in which the 16 MBTI personality types are distributed into four temperament groupings, which are then compared against their proficiency in engineering design. Stronger students, in particular, may be unhappy about instructor-assigned teams; however, understanding that they will not be able to choose their co-workers in their careers helps them accept this kind of team formation (Oakley et al., 2004). It is also suggested that team roles be rotated so that everyone in a group has a chance to experience all the roles and practise them, as well as to understand task interdependence (Clinebell & Stecher, 2003; Felder & Brent, 1994). The results here could point to a specific way of organizing teams for better performance.

Peer evaluations are an important tool in teamwork. They allow team members to know how they are doing and give their peers feedback, which they can use to reflect on their own progress if the evaluation is done early enough (Gomez Puente et al., 2013; Oakley et al., 2004). Peer evaluations also provide a way to increase accountability and control behaviour (Clinebell & Stecher, 2003; O'Neill et al., 2018). Peer evaluation is assumed to be objective and valid since it is based on real contributions from members and is not a subjective perception affected in part by personality types (Ostafichuck & Naylor, 2017); it is a useful supplement to other grades in the course and can be an accurate measure for the instructor to establish the contribution from each member and adjust grades accordingly (Oakley et al., 2004).

Team dynamics have a critical effect on results. Positive team dynamics and interactions will lead to higher-quality performance and team output (Streiner et al., 2010). Collaboration is also a key factor in team interactions (Kozlowski & Chao, 2018; Streiner et al., 2010). How team members interact and exchange information will have an effect on the outcomes of their efforts (Kozlowski & Chao, 2018). Next, the literature on factors that can influence individual and group performance is discussed.

2.9. Influential factors for individual performance

The Big Five personality traits have been studied as predictors of educational performance. Openness is defined as being imaginative, curious, broad-minded and intellectual; consciousness is being orderly, responsible, dependable and achievement striving; extraversion is being talkative, energetic, sociable and assertive; and neuroticism is being neurotic, worried, anxious and angry (Barrick & Mount, 1991; John & Srivastava, 1999). In their review of empirical literature on the Big Five as predictors of post-secondary academic achievement and meta-analysis, O'Connor and Paunonen (2007) identify conscientiousness as most consistently linked to different indicators of academic success, including grade point average (GPA). Conscientiousness is often interpreted in terms of motivation, and there is assumed to be a logical relation between behaviours of some facets of conscientiousness and performance. They also found that measures of openness have been predictors of GPA and performance; however, there is a less prominent correlation in the rest of the literature. O'Connor and Paunonen found very few correlations with the other Big Five factors. In another meta-analysis of job performance and personality dimensions, Barrick and Mount (1991) also found that conscientiousness was a consistent predictor of job performance. Their results also show that openness and extraversion are predictors for training proficiency and ability to learn, which could lead to good performance. Individual job performance across multiple occupations and cultures has also been shown to have a significant relationship with conscientiousness (Neuman et al., 1999; O'Neill & Allen, 2011). In their examination of academic performance predicted by personality traits, Chamorro-Premuzic and Furnham (2003, p. 245) concluded that "conscientious, stable and introverted individuals would be more likely to succeed in university-based academic settings". They found that there is a significant positive correlation between conscientiousness and academic performance and that extraversion and neuroticism both significantly correlate negatively.

2.10. Influential factors on team performance

The interaction of different people and personalities in teams may cause circumstances of low productivity and poor experiences (Clinebell & Stecher, 2003). Past research shows that personality traits and their composition in teams are closely related to team performance (Chiang, 2011; O'Neill & Allen, 2011; Sherif, 2018). Many studies have proven that Big Five traits are able to predict team performance (Chiang, 2011). Out of the five Big Five traits, consciousness seems to be the most prone to influencing teamwork in a project-based learning environment. It determines how each member will carry out their tasks for their project, thus affecting the outcome of the entire team. O'Neill & Allen (2011) found it to be one of the most consistent Big Five trait predictors of job and team performance, and Hua (2013) showed that it is significantly correlated with team performance. Bradley, Klotz, Postlethwaite & Brown (2013) demonstrate that teams with a high level of openness have been shown to perform better because open-minded people tend to have more positive attitudes, are more adaptive and promote open discussion in teams. They explain that collaborative teams tackle conflict and enable constructive debate. Teams with lower neuroticism (high emotional stability) also tend to use good conflict-resolution strategies because they are level-headed and view themselves and others positively. In a meta-analysis of the Big Five effect on team performance, Peeters et al. (2006) also show positive correlation of agreeableness and conscientiousness with team performance. In addition, O'Neill & Allen (2011) argue that a high level of conscientiousness, agreeableness and openness leads a team to perform better. They also state that having people with lower neuroticism and a mix of extraversion is good for a team. Homan et al. (2008) argue that diverse teams that score high on openness will perform well. On the other hand, Humphrey et al. (2007) explain that self-managed teams should be formed with a maximization of extraversion variance for role differentiation and a minimization of conscientiousness variance for goal congruence.

Social loafing, defined as when individuals exert less effort when working in a team, leading to less productive groups, has been demonstrated by Sherif (2018), through a qualitative case study, to be linked to low scores on each of the five factors, openness, conscientiousness, extraversion, agreeableness and neuroticism. The loafer is described as uncreative/not open to new ideas, unorganized, introverted, selfish and emotionally stable (Sherif, 2018). The morale of a group, and therefore its productivity, will suffer as the more conscientious students carry the burden of those who do not participate (Clinebell & Stecher, 2003).

Various other relevant factors also influence team performance. GPA, which can represent motivation and capability, has also been proven to be a significant factor for team performance (Hacker, 2000). Gender and racial diversity have reported mixed results, having found either to be beneficial to performance (by including diversity) or to have no significant impact (team members don't notice or push past the differences) (Hua, 2013). Personality traits have been linked to cultural factors, which in turn influence social behaviours and team performance (Chiang, 2011; McCrae & Costa, 2003). According to Vaz et al. (2013), the impacts of project-based learning differ by gender, and gender affects how students approach project work. They argue project-based learning approaches might be more interesting for women and cause them to do better. Women have also been found to be more motivated by a social context and collaboration (Busch-Vishniac & Jarosz, 2004; Holbert, 2016). These factors are also useful for understanding team relationships and improving efficiency.

3. Chapter 3 - The Role of Makerspaces in Inclusivity in Engineering

3.1. Objectives

Many organizations and communities seek to understand their level of inclusion and ways to increase it (Jansen et al., 2014). There has been a recent widespread integration of maker communities in formal engineering educational settings through project-based learning (Blikstein, 2018; Talley et al., 2017). Makerspaces are shown to offer opportunities that may bridge gaps in academic knowledge in addition to social and economic inequalities (Hughes, 2017). It is important to understand their ability to be inclusive and the barriers that may be present. The objectives of this research include the study of certain demographic factors (gender, program of study, year of study, country of origin) on student perception and behaviour with regards to feelings of inclusion in the maker community and in the University of Ottawa Faculty of Engineering. This study examines the effect of two cornerstone engineering design courses offered at the University of Ottawa and the makerspaces in the Faculty of Engineering on students' feelings of inclusion in two parts.

The first part of the research in this chapter identifies a baseline inclusion level in the student population. Research was conducted by collecting quantitative data via surveys to capture information from a large amount of people and be able to make inferences (Borrego et al., 2009).

This study aims to answer the following questions:

- What are the baseline inclusion level trends for engineering design students in the making community and the Faculty of Engineering?
- What is the influence of the uOttawa makerspaces on feelings of inclusion for engineering design students in the making community and the Faculty of Engineering?

The second part of the research in this chapter aims to discover reasons for varying levels of inclusion and the impacts of inclusivity in the making and engineering communities, as well as to understand the experience of students participating in this environment. It also aims to identify ways inclusion can be increased through makerspaces and design courses. This interpretive research is done with qualitative data from interviews with the following guiding questions:

- What factors influence inclusion in a making environment?
- What factors influence inclusion in an engineering school environment?

3.2. Methods

The research paradigm for this study is an explanatory mixed-method approach (Borrego et al., 2009) used to understand how people see and interpret their experiences and to build theory as the study progresses. The quantitative phase uses statistical analysis from online survey answers and helps identify participants for interviews in the qualitative phase. The qualitative phase was then used to understand reasons for feelings of inclusion. It is important for researchers to put themselves in the shoes of the participants to better comprehend what factors may affect their feelings of inclusion. The University of Ottawa's office of research ethics and integrity has approved the data collection for this research (file H-09-18-1124).

3.2.1. Quantitative study

First, a quantitative approach was implemented through an online survey to capture information from a large number of people and be able to make inferences (Borrego et al., 2009). An inductive method was used to avoid influences of preconceptions on the research data in this explanatory study. The students in the engineering design courses were the primary sample.

The students were surveyed about their feelings of inclusion as makers and as engineers. Two different inclusion surveys were used to be able to validate the results: the perceived group inclusion scale (Jansen et al., 2014) and the psychological need-satisfaction scale (Sheldon & Bettencourt, 2002), both of which can be found in Appendix A. Both surveys looked at perceptions of authenticity and belonging within a group. The surveys were administered in the first few weeks of the semester and again in the last week to all cornerstone engineering design course students. Results were collected in the fall 2018 and winter 2019 terms as part of the normal operation of the courses. The dataset includes 191 people. A comparison of means was done with the survey results between perception of inclusion and gender, program of study, year of study or country of origin to look for significant differences and explore trends in baseline inclusion levels.

3.2.2. Qualitative study

Second, a qualitative approach was implemented through one-on-one interviews. Purposeful sampling was used to select participants to ensure they were knowledgeable about the topic, were willing to participate and speak about their experiences and were the optimal cases for this research (Bryant & Charmaz, 2007, Chapter 11). Participants were among design course students and active members of the uOttawa makerspace community to discover factors that influence inclusion in making and engineering school environments.

Semi-structured interviews were conducted with 7 participants (3 men and 4 women). Their self-reported characteristics are listed in Table 2. Each participant was interviewed once, and interviews were conducted in the summer of 2019 and summer of 2020. Broad, open-ended questions were asked, following intensive interview principles (Charmaz, 2006) to explore in depth a particular topic. These principles allow the interviewer to request more details or explanations and ask about the participant's thoughts, feelings and actions to follow up on leads that emerge during the interview. The method is open-ended and flexible yet is a directed conversation to gain insight into the participant's experiences (Charmaz, 2006). The interview protocol was revised between each conversation to consider any emerging paths following the reflection and debriefing for each interview. Each participant was also asked to fill out an inclusion survey, explained in the quantitative study, before their interview, and the results were discussed during the session.

Table 2. Qualitative participant details

Name (pseudonyms)	Year of study	Program	Gender	Ethnicity
Daniel	6th	Mechanical engineering	Male	White
Hannah	4th	Human kinetics (previously biomedical mechanical eng.)	Female	White
Leo	3rd	Biomedical mechanical engineering	Male	White
Maggie	4th	Electrical engineering	Female	White

Maria	Graduated 1 yr previously	Chemical engineering	Female	Arab
Max	6th	Computer engineering	Male	Arab
Zoe	1st MASc	Civil engineering	Female	Arab

Audio recordings were kept of each interview, then used to transcribe the conversations in MS Word. Notes and memos were kept in Google Drive. The transcripts were then imported into NVivo software and coded. Grounded theory method is a systematic, inductive and comparative approach for conducting inquiry for the purpose of constructing theory and encourages researchers' persistent interaction with their data (Bryant & Charmaz, 2007). Grounded theory methods were used to code and analyze, to offer a "conceptual explanation of a latent pattern of behaviour that holds significance within the social setting under study" (Bryant & Charmaz, 2007, p. 268) and to remain open to the emergence of theory.

In the initial coding stages, structural coding was used to segment data related to different research questions and the conceptual framework of inclusion, in keeping with appropriate methods for dealing with data on multiple participants and from semi-structured interviews (Saldaña, 2013). Second, descriptive coding was done to summarize topics for each section to index the data's content (Saldaña, 2013). As each interview was coded, the list of codes, or codebook, was updated and refined as the analysis continued. In the second, focused, stage of coding, axial and focused coding were used to sort, reintegrate and organize the data (Charmaz, 2006) into three main categories, as presented in the final codebook in Appendix C: identity, group membership and authenticity. Finally, an inter-rater reliability test was conducted with a PhD student who independently coded an interview (about 14.3% of the data) according to Miles & Huberman (1994, p. 64) to check the reliability of the codes. The reliability was found to be 88.4% and differences were reconciled by clarifying and revising the code descriptions.

After the two main phases of grounded theory coding were completed, code mapping and memo writing were used to reorganize and combine categories to identify three central themes:

- Connecting with identity: this category was made to understand how students connect with others and encompasses the relatedness need of inclusion theory; it captures codes like interests, skills and identity.

- Participation: this category was made to understand the role of participation in belonging and includes codes like value and group affection.
- Distinctiveness: this category captures codes related to authenticity and personal distinctiveness, given that feelings of inclusion can be heightened when an individual feels accepted as being unique and authentic; it therefore includes attributes related to uniqueness and authenticity.

Patterns and themes were analyzed and discussed during debriefing sessions and are reported in the findings in section 3.5.

3.3. Metrics

3.3.1. Inclusion tools

The perceived group inclusion scale (Jansen et al., 2014) and the psychological need-satisfaction scale (Sheldon & Bettencourt, 2002) surveys were used to understand levels of inclusion within engineering and making. They collected quantitative data on a 5- and 7-point Likert scale, to measure inclusion within the specific groups of "maker" and "engineer," as well as personal identifiers including gender, year of study, program of study and country of origin. The students' baselines levels of feeling included were converted to a percentage. See Appendix A for the survey questions used to determine scores for feelings of inclusion. The following definitions of the groups "maker" and "engineer" were provided to the students with both sets of survey questions:

Maker: "Activities focused on designing, building, modifying, and/or repurposing material objects, for playful or useful ends, oriented towards making a 'product' of some sort that can be used, interacted with, or demonstrated." (Martin, 2015, p. 31)

Engineer: "Engineering practice is not simply a problem-solving process and specialized knowledge. It is the complex, thoughtful and intentional integration of these towards some meaningful end." (Sheppard et al., 2006, p. 435)

The survey results were also discussed with the interview participants.

3.3.2. Interview protocol

An interview guide was used during the conversations with the participants of the study. It was revised between each interview. The final set of questions is included in Appendix C.

3.3.3. Other metrics

Demographic information on gender, program of study, year of study and country of origin was used to identify trends in the population of students and the effect of these factors on perceptions of inclusion.

3.4. Quantitative results and discussion

Since both the uOttawa Makerspace and the number of students taking engineering design courses have expanded significantly, more people than ever will be exposed to them, so there is value in studying and understanding their effect on the feelings of inclusion within the Faculty of Engineering and within the maker community. It is also important to understand how student experience and retention could be improved, given that the feeling of being included in the engineering community (and of forming an engineering identity) is crucial to students committing to engineering during and after graduation (Stevens et al., 2008).

The following sections describe the steps taken to answer the question "What is the influence of the uOttawa makerspace on the inclusion of engineering design students within making and the Faculty of Engineering?" First, a baseline of the pre-course results is outlined. Second, the two survey tools are compared. And finally, the pre- and post-course inclusion score differences are analyzed.

3.4.1. Baseline inclusion scores

Using the baseline inclusion scores calculated from the two online surveys outlined in 3.3.1, a Spearman's Rho correlation was run to determine if the baseline making and engineering scores were related. It measured the strength and direction of the relationship of these two continuous variables (Lund Research, 2013). There was a statistically significant, strong positive correlation between both groups, $r_s(183) = 0.802$, $p < 0.05$, leading us to believe that most students had the same feelings of inclusion in the maker community and the engineering community and may not even differentiate between them.

The following sections explore the variation in inclusion scores by gender, program, year and country of origin for the maker community and the engineering community before taking the design course.

3.4.1.1. Gender

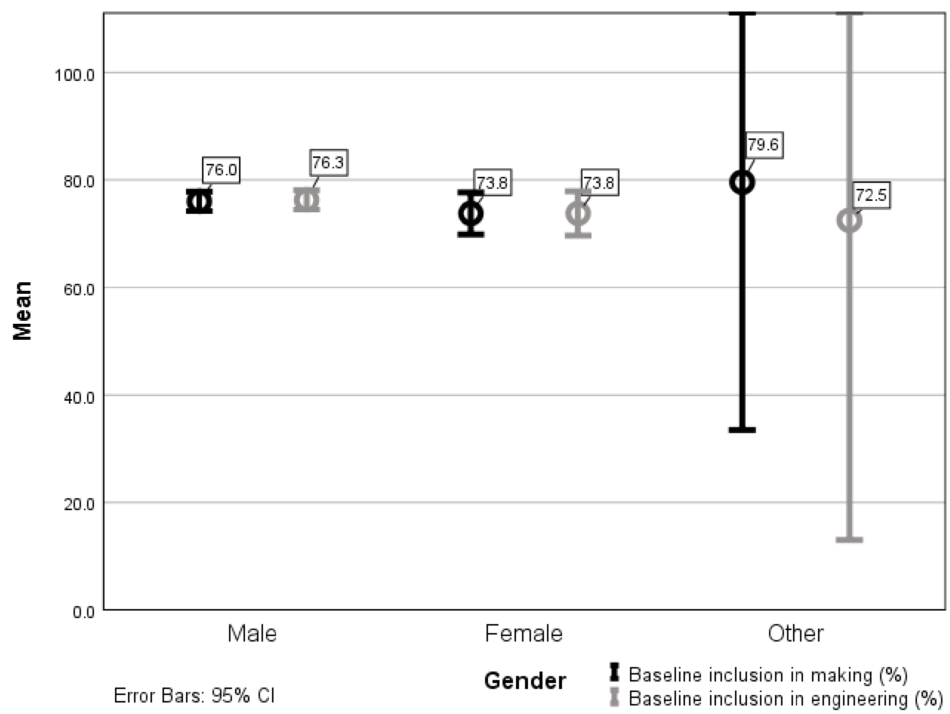

Figure 1. Baseline feelings of inclusion by gender

For each gender, there was no difference between feelings of inclusion in making and in engineering. However, a larger variation in scores and a lower mean for women than for men was observed, as shown in Figure 1 and Table 3. This leads to the conclusion that women could feel less included in both groups. The Other participants will also not be considered based on the unrealistic confidence intervals in Figure 1 and the low number of participants. The dataset includes outliers that are considered genuinely unusual therefore Kruskal-Wallis non-parametric tests were conducted to determine if there is a significant difference between the two independent gender groups (male and female) on the continuous inclusion variable (Lund Research, 2013). The maker and engineer differences in gender were, however, shown to not be significant based on the tests, $\chi^2(2) = 1.188$, $p = 0.552$ and $\chi^2(2) = 1.857$, $p = 0.395$ respectively.

Table 3. Baseline feelings of inclusion by gender

Gender	Number	Mean score: maker	Std. dev.: maker	Mean score: eng.	Std. dev.: eng.
Male	142	76.03	10.87	76.29	10.91
Female	46	73.77	13.18	73.78	13.81
Other	3	79.58	18.55	72.50	23.95

Note: See Appendix A for surveys used to determine scores for feelings of inclusion. Scores are out of 100.

3.4.1.2. Program of study

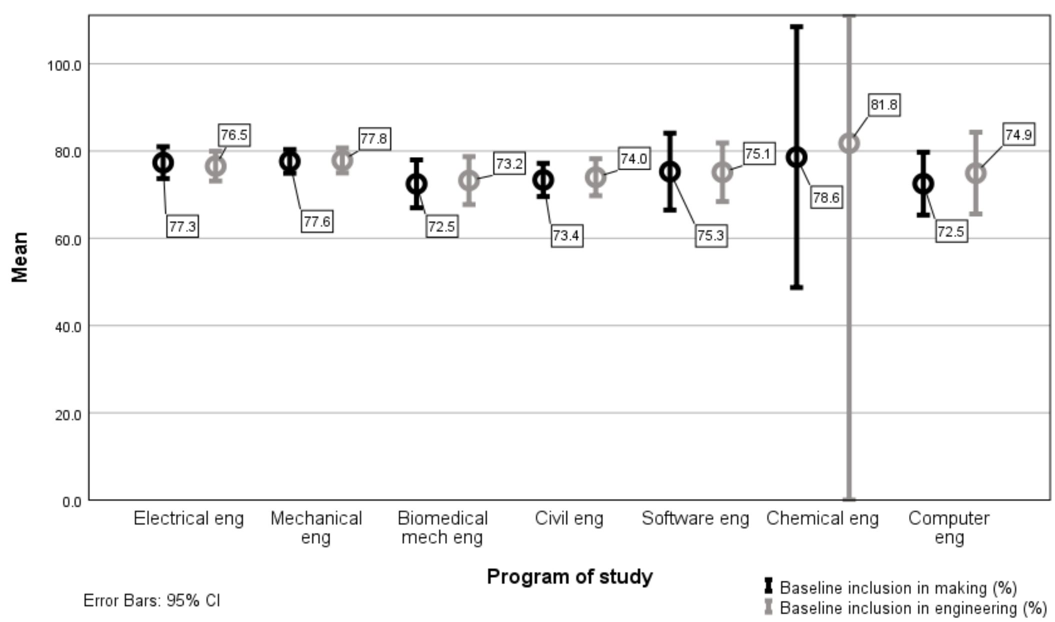

Figure 2. Baseline feelings of inclusion by program of study

The program of study showed some difference in inclusion scores for both making and engineering; however, the means were all around 75%, with the confidence intervals showing values between 65% and 85%, excluding chemical engineering. (See Figure 2.) A Kruskal-Wallis test was again conducted to determine if there were significant differences in the average baseline inclusion scores for both communities for program of study since genuine outliers were present. The maker and engineer differences between programs were shown to not be significant, $\chi^2(7) = 6.205$, $p = 0.516$ and $\chi^2(7) = 5.451$, $p = 0.605$ respectively.

There was an exception in mean and standard deviation distribution of scores between feelings of inclusion in making and in engineering for both chemical and computer engineering, where the difference is bigger. There was a larger variation for chemical engineering because there were only two students in this sample. Students in computer engineering seem to feel less like makers than engineers, with a tighter grouping at a lower mean. The scores for feelings of inclusion in each program are shown in Table 4. Biomedical mechanical and civil engineering have lower average feelings of inclusion than the other programs. Biomedical mechanical engineering has 43% female students in this sample, something that could lead to a lower mean as discussed in the previous section. However, civil engineering has only 21% female students, and its mean was only slightly higher than that of biomedical mechanical engineering. The relationship between programs should be studied further to understand what other effects could influence the inclusion scores.

Table 4. Baseline feelings of inclusion by program of study

Eng. program	**N**	**Mean score: maker**	**Std. dev.: maker**	**Mean score: eng.**	**Std. dev.: eng.**
Electrical	43	77.33	11.93	76.53	11.05
Mechanical	58	77.64	10.33	77.85	10.85
Biomedical mechanical	21	72.48	12.06	73.24	12.07
Civil	44	73.38	12.46	73.99	13.96
Software	9	75.28	11.45	75.14	8.76
Chemical	2	78.60	3.33	81.79	9.60
Computer	7	72.52	7.79	74.93	10.12

Note: See Appendix A for surveys used to determine scores for feelings of inclusion. Scores are out of 100.

3.4.1.3. Year of study

The year of study showed similar results. All years seemed to have similar inclusion scores for making and engineering, as shown in

Table 5. In making, similar results in different years were expected; however, in engineering greater variation was expected, with students in fourth year feeling more included in engineering. This may not be the finding here because the numbers of students in third and fourth year in the sample are low. The Kruskal-Wallis test was conducted to determine if there were significant differences in the average baseline inclusion scores for both communities against year of study since outliers were present. The maker and engineer differences in year of study were not shown to be significant, $\chi^2(3) = 0.538$, $p = 0.910$ and $\chi^2(3) = 0.959$, $p = 0.811$ respectively.

Table 5. Baseline feelings of inclusion by year of study

Year	N	Mean score: maker	Std. dev.: maker	Mean score: eng.	Std. dev.: eng.
1st	112	75.48	11.29	76.00	11.45
2nd	58	75.15	12.36	74.64	13.15
3rd	9	78.71	8.21	76.53	9.96
4th	12	75.59	13.21	76.26	11.52

Note: See Appendix A for surveys used to determine scores for feelings of inclusion. Scores are out of 100.

3.4.1.4. Country of origin

The origin variable was constructed based on the respondents' country of origin answer: Canada is local, and everything else is international. The students' country of origin was not shown to make a difference in their scores for feelings of inclusion in making or engineering, with Kruskal-Wallis tests ($\chi^2(1) = 0.519$, $p = 0.471$ and $\chi^2(1) = 0.016$, $p = 0.898$ respectively). The relationships can be seen in Table 6.

Table 6. Baseline feelings of inclusion by student origin

Origin	N	Mean score: maker	Std. dev.: maker	Mean score: eng.	Std. dev.: eng.
Local	121	76.04	11.53	75.51	11.99
International	70	74.68	11.65	75.83	11.73

Note: See Appendix A for surveys used to determine scores for feelings of inclusion. Scores are out of 100.

3.4.2. Survey tools

Two different tools (the perceived group inclusion scale and the psychological need-satisfaction scale) were used to determine the validity of the results: the first was used in the fall 2018 semester, and both were used in the winter 2019 semester. Since genuine outliers were again present, Kruskal-Wallis tests were conducted to determine if there were differences in the average survey scores of baseline making, baseline engineering, delta making and delta engineering between these tools.

Table 7. Kruskal-Wallis tests on survey tools

	Base: maker	Base: eng.	Delta: maker	Delta: eng.
N (1st tool)	150	150	63	63
Mean (1st tool)	76.200	76.525	1.845	1.964
N (2nd tool)	41	41	7	7
Mean (2nd tool)	73.124	72.334	4.762	6.803
$\chi^2(1)$	1.882	3.824	0.230	2.250
p	0.170	0.051	0.631	0.134

None of the tests were significant ($p > 0.05$), indicating the means between the two tools were not significantly different and represent feelings of inclusion in the same way. However, it should be noted that there are some limitations which can change this conclusion. First is the number of observations which is very low and makes a definitive result more difficult to justify.

Second is the significance of the baseline engineering score comparison which is almost indicative of a significant result ($p < 0.05$). More observations are needed for a clear comparison however both tools will be considered valid and can be used in this case.

3.4.3. Difference in inclusion scores due to intervention

The delta inclusion scores were calculated based on the difference of the pre-course scores at the beginning and post-course inclusion scores at the end of the semester. For each factor, since there are outliers in the dataset, Kruskal-Wallis tests were again conducted to determine if there were significant differences in the average delta scores for the making and engineering communities. When looking at the delta in the making and engineering inclusion scores, there was no significant difference for any of the factors, as demonstrated below ($p > 0.05$).

Table 8. Kruskal-Wallis tests on delta scores

Community	Factor	Test statistic	p
Maker	Gender	$\chi^2(2) = 4.187$	0.123
Maker	Program of study	$\chi^2(8) = 7.940$	0.439
Maker	Year of study	$\chi^2(3) = 1.828$	0.609
Maker	Origin	$\chi^2(1) = 0.002$	0.965
Engineering	Gender	$\chi^2(2) = 1.750$	0.417
Engineering	Program of study	$\chi^2(8) = 5.347$	0.720
Engineering	Year of study	$\chi^2(3) = 1.177$	0.759
Engineering	Origin	$\chi^2(1) = 0.087$	0.769

Next, a paired-samples t-test was used to determine whether there was a statistically significant mean difference between the pre- and post-course making inclusion scores. Data are mean ± standard deviation. There were no outliers in the data, as assessed by inspection of a boxplot. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p = 0.058$). Participants did not report a statistically significant difference ($p = 0.169$) in making inclusion scores between the pre-course (75.494 ± 10.495%) and post-course (77.631 ± 11.839%) scores. For engineering, since the data is not normal and has outliers, a Wilcoxon signed-rank test was conducted to determine the effect of the intervention on inclusion scores. The difference scores were approximately symmetrically distributed, as assessed by a histogram. Of the 70 observations, the post-course scores showed an increase in inclusion levels in 35 observations, whereas 9 observations saw no improvement and 26 observations saw a decrease in scores. There was no statistically significant median increase in engineering inclusion levels (0.625%) by the end of the course (78.750%) compared to the beginning of the course (73.750%), $z = 1.54$, $p = 0.124$.

The reason there was no significant difference here might stem from the fact that a 12-week semester is not long enough for a feeling of inclusion to change. Further research should be done over a longer time frame to try to measure any effect. Other groups, such as engineers who are not taking one of the two design courses and makers who participate in the Makerspace, should also be tested to establish a comparison for this group of students. Changes over the course of the semester are also not necessarily owed to this intervention, the design course. Many other factors could come in to play which are not captured by the administered surveys.

3.5. Qualitative results and discussion

The three identified themes related to group inclusion in making and engineering based on the coding and analysis of the interviews — connecting with identity, participation and distinctiveness — are presented in the findings and discussed in the discussion section. Each theme suggests evidence for why a student may or may not feel included in each community. The making and engineering communities are mostly presented separately, with a few ties between them.

3.5.1. Findings

3.5.1.1. Connecting with making and engineering identity

There are many different avenues to connect with people, including by identifying with another person or a group of people, based on their traits, skills or interests, and through personal interactions like working on projects with a group.

Connecting with making identity

When looking at the identity of the making community, all interviewees described a maker as being a person who fabricates/creates/tinkers and either implicitly or explicitly referred to a physical creation, as Maggie and Max described:

"People who tinker with things and, you know, doing random design projects and just any kind of creative project on the side." — Maggie

"Making things, you know, like manipulating things, because you know what they do and their properties and stuff and you would have this idea in your head like, oh, this thing does this and this thing does this, if I put them together they make this." — Max

Many participants also said makers are problem-solvers who engage in creative design while being hands-on. However, many also stated that the maker community is large and diverse and encompasses many types of people and experiences, features that make it hard to come up with one definition. This leads to the impression of a more inclusive community that is more accepting.

"Part of being in that maker sphere is like there's a lot of diversity in it, so I definitely feel like part of the diversity as opposed to part of the black and white beginning of it." — Maggie

Although making is often associated with technical processes, three participants explained that making includes more than just the technical aspect but also the textile and art sides as well. The majority of interviewees referred to makers as people who participate in making activities on their own time for a small personal project, as Hannah explained:

"I feel like it's more creative and more for one's personal benefit — just because they enjoy making, things like that." — Hannah

Everyone said being a maker partly stems from your personality, a family trait or part of your background. Zoe explained that is why she does not and will not feel like a maker.

"Some people who their forte is in spatial, mathematics, analytics, whatever. Mine was very strongly on the mathematical, analytical. I'm not a tactile learner, I never grew up that way, and it's weird for me. […] It's like, you learn by touching — that's just more complicated for me." — Zoe

"I feel like making has been part of me since I was little." — Max

Two participants, Daniel and Max, were confident about their association with making. Four participants, Hannah, Leo, Maggie and Maria, connected themselves to making in some way but were not sure about fully being makers, and Zoe said she is not a maker. The main reasons they stated for identifying or not identifying as makers were related to their perception of the general making identity or their personal background and connecting with other makers.

Maggie and Hannah said they are not really makers because they do not have a strong technical background, unlike the other makers they see. There was the same implication in Maria's case.

"I wanted to be a maker but I didn't know how to be — because if you're going for the technological sense, I didn't know how to code and it's just such a big black box of questions that I didn't know how to enter it. But, like, in my head I was always like 'I want to, that would be helpful to have this thing.' So I was thinking like a maker but I was not doing anything." — Maggie

Leo's thoughts were slightly different. His definition of a maker was someone actively making and creating, so he saw himself as a maker only when he was in a makerspace working on something.

"I guess I identify with the idea. In practice, I'm a little bit too lazy to actually do any of that. But maybe in the future. […] I kind of feel like while I'm in the makerspace, I'm a maker." — Leo

Daniel participates in an online making community, and he said he is a maker because his hobbies are related to making: fabricating, 3D printers, and making pens and props. Max says he is "definitely" a maker because he has been a maker since he was young. Max also identified strongly with people who participate in the maker community.

"And I think she's going through the same stuff, and it makes me feel like, you know, kind of more like, 'this is my clique, this is my gang, makerspace people'." — Max

Making was described as a personal activity without much collaboration on projects but at the same time as taking place within a helpful community where people help each other out and give advice to solve problems.

"But I do feel like everyone is very helpful because everyone goes through the process of iterating, and people tend to really want to help each other out. I notice it often, like, 'Oh, you're doing this? Do it this way.' People actually go out of their way and give advice." — Zoe

Interacting with others in the making community is an important aspect of learning, improving and getting support for Daniel, who participates in an Instagram making community where there is more "dynamic engagement."

> *"One of our biggest efforts is either showing support to other people, communicating with them in that way, but also just being able to see what somebody else is doing, and people see what I do as well. Even if it's sometimes not exactly what you think, it gives you creative ideas to go and implement something or, 'Oh, I never thought to do this that way' […] and I feel like that kind of summarizes the importance of the online community side of things, where there is almost a support group in a kind of way […] and I could say, 'Oh, does anybody know?' and tag a few people, and you can get feedback that way too." — Daniel*

Connecting with engineering identity

Engineers were described as problem-solvers by five interviewees. Engineers were also associated with a professional environment or career in which people design, build and innovate. Engineers were also said to apply information and implement practical sciences to achieve their goals.

> *"An engineer is a problem-solver that follows, like, codes and protocols and tries to either solve a problem or make something, innovate." — Max*

> *"Engineering, the community overall, has more professionalism in it, in its nature." — Daniel*

Because the interviewees were students, the interviews touched on interacting and connecting with other students and the Faculty of Engineering and also connecting with the profession of engineering. There was a lot of variation between participants in this regard. Daniel did not feel included in the Faculty because of problems with professors and the administration; however, when referring to the profession, he said he can "communicate with most engineers pretty effectively" and has "a certain fundamental relation with any other engineering person just from the background that you've all gone through." Max had similar thoughts about being able to "click on a bunch of things" with other engineers and did not make a distinction between students and professionals engineers. Maria was the opposite from Daniel, in that she connects with her classmates through their interests in certain topics but feels out of place in the profession being a woman and being involved in social entrepreneurship. Leo, on the other hand, said he fits in but seems to have no desire to connect with either the student community or other professionals and explained that there are not many similarities between the people.

> *"It's just a collection of people who picked the same job to go into out of university. It's a career, you know, area. It's very good career area, high paying and easy to get a job. But I would sort of say nothing unites us beyond that. […] However involved I want to be is how involved I end up being." — Leo*

Hannah said her classmates have different interests than she has: "People would be talking about, all excited, about things, and I'm kind of feeling on the outs of that." This feeling was one of the factors that contributed to her switching out of the engineering program. Like Max, Maggie doesn't differentiate between the stereotypes about engineering students and professionals. She said she doesn't identify with any particular engineering stereotype but that "I feel like kind of a combo of all of those things, but I feel like I do belong within the realm of engineering."

Daniel, Maggie and Zoe hesitated to identify strongly with the word "engineer" because they were still in their studies and engineering is a regulated profession in Canada where you are not legally called an engineer until you get a professional engineer licence (P.Eng.). Zoe went as far as to doubt whether she will even like the "real" engineering in industry, although she did connect to engineering in the second half of her undergraduate degree program because the "courses started making more sense."

> *"I haven't left the university bubble yet, so I'm kind of keen to get out there. I'm curious what's going to happen once I'm actually truly in the industry or in the private sector, in the government, working as an engineer. I'm curious, because I still don't know if I'm going to like it or not. I'm kind of worried. There's actually a part of me that's concerned that I might not enjoy it." — Zoe*

3.5.1.2. Participation

Participation in a group or within a community can have an impact on the value the participants feel they bring to the community, how much the community values them and how members of the group feel about each other. Participation can also lead to connections between people and opportunities to learn.

Participation in making

Since making has been defined mainly as working on physical personal projects, Leo, Maggie and Maria said they don't quite feel like makers even though they participate in making and help other makers. Those who conceptualize and plan making activities or projects but do not do the hands-on work are not seen as "real" makers.

> *"I tried to make and build things to solve problems, but I also try to learn about the whole process and what goes behind it to produce stuff, so I might not be the person who is making things all the time but could be the person supplying in the fund, the knowledge, uh, the measurements. That's why I said [maker] by association." — Maria*

At the same time, Maggie and Maria said they can bring value by helping and teaching others in the makerspace, providing support that allows them to be more confident in their skills and leverage the maker community to do "anything," as Maria stated: "You are empowered to solve anything, you can do anything, you can make anything you want." Daniel said he adds more value when he is volunteering his time because he can usually contribute different skill sets to an area, which is typically what happens in a making context. Because of the helpful nature of the community and the diversity within it, it is also easy to contribute and prove your value to be accepted and included in making. Daniel and Max also both said they feel valued as makers because they can offer advice and help to anyone who asks.

> *"It's very easy in the maker sphere to prove your value. If you're a six-year-old or if you're an 80-year-old doesn't matter — you just, like, within one conversation, I think, usually, yeah, it gets inclusive." — Maggie*

Although Zoe described herself as not belonging to making, she said, "you feel valued if you add value." Since she had a managerial role in the makerspace helping people, she felt she could still add value and be accepted by the community even if she is not a maker.

However, the making community was not always seen as being accepting. Maggie, Maria and Hannah talked about others in the making community who cast doubt on their skills and their place in the community when they are in the makerspace. They mentioned people, generally male, who are comfortable in the makerspace, know a lot about making and technology and look down on those perceived as not knowing as much. Some participants also had the impression that if they are not technological makers, they are not widely accepted in making.

Participation in making allows for a better understanding of the community as a whole beyond the typical technological maker definition. Maggie explained that she was able to use her creativity, see other sides to making and be less intimidated by the technology once she was participating in the community, but that she had to come in with a learner's mindset.

"But because of how I was, I guess, introduced to the more, you know, legitimate maker world, I didn't feel excluded because I came in with, like, a learner's mindset and was accepted with, like, a learner's mindset." — Maggie

When asked about the relationship between making and engineering, all participants agreed that they were separate but had some connections. Max and Maggie thought all engineers should be makers and that these people would be better engineers. Zoe said making bridges a gap between the academic world and the tactile. Hannah explained that she wanted to work with prosthetics because she likes the biomedical aspect, is good at math and likes making. She initially perceived engineering and making to be the same, so she applied to study engineering. However, after a few years in engineering, realized she could work on prosthetics and pursue making without being an engineer.

Participation in engineering

Participating and learning in the engineering program gave Maria the confidence to tackle other complicated subjects. Daniel explained that he can bring value to the workplace because of his different perspective and is valued by his peers because of his practical experience. Working for engineering companies and getting positive feedback from his bosses has also made him feel more valued than getting feedback from peers.

"I feel more valued from a professional standpoint in engineering particularly." — Daniel

Maria, Maggie and Zoe said they are valued in engineering because of their job or roles but they are not valued because of their engineering skills specifically. Similarly, as Hannah was learning new skills in her design project, it made her feel more valuable to her team while at the same time becoming more valued by her team. For Leo, the personal interactions while working on his design project with his group made him feel more connected and included with engineering but actually had a negative effect afterwards because of the letdown of no longer being connected. He did contradict himself, however, by saying he doesn't care to connect with others and that "everyone is just sort of doing their own thing."

> *"Leaving that would probably decrease the percentage because suddenly I have an idea of what being more connected looks like. And I'm going back to being less connected." — Leo discussing his survey scores*

Max said he feels valued in engineering but that his makerspace participation is a reason he is not doing well in school.

Participation in the Centre for Entrepreneurship and Engineering Design (CEED)

All participants had been involved in one or multiple ways with the Centre for Entrepreneurship and Engineering Design. Daniel, Maria, Maggie, Max and Zoe were employees of different spaces in CEED. Maggie, Max, Hannah and Leo had already taken one of the engineering design courses. Participating in these activities had an impact on their journey in making and engineering.

Maggie and Max had been exposed to the maker world in a minor way previously, but the courses propelled them into the maker world and deepened their involvement in it. Both started working for CEED afterwards.

> *"Yeah, I think the 2101 class is like a nose-first dive into that maker community […] so I would say it did change my perspective into this community and it did change my involvement into the community a lot." — Max*

They identified a few elements of the design courses, such as the client involvement and designing a full system, that are related to engineering. The strongest element of the courses, however, was their ability to develop their making skills.

Hannah said the design course was her favourite engineering course because she loved the wood shop and making aspect of it where she could learn to use new tools. It also gave her a better understanding of the engineering design process from the start to the end of a project. It gave her a full view, including elements like intellectual property and regulations, and led to her discovery that engineering was more than just making. Leo described the course as a way to "open my eyes to the process of engineering, the practical stuff" and spend time with classmates. He was able to discover all the things that are possible in a makerspace and a making environment.

Zoe explained that because of her job, she was able to make connections with other employees in the Faculty and other students, enabling her to feel closer to the campus community. She also developed many skills, including managerial ones because of her management job.

3.5.1.3. Distinctiveness

Discussions related to authenticity and personal distinctiveness included characteristics like gender, ethnicity, skills and interests.

Acceptance as a distinct individual in making

In relation to making, all participants except Max said they are different from other people in the community. Maria cited personality differences ("not as geeky as them"), whereas Daniel, Hannah and Maggie cited skill and background differences.

> *"I'm not coming from a technological background." — Maggie*

> *"I have a background in manufacturing and all these other things related to engineering. I feel like I follow the rules a little bit more." — Daniel*

Even though they identified differences, all participants explained that they can express their differences in the community freely. Most described the making environment as inclusive and diverse and a place where differences are not necessarily noticed.

> *"I feel like it's a bit easier in the making community because differences are nice, and things are different. Diversity is a bit more welcome, I find, in making." — Zoe*

Maria and Zoe talked about women being a minority and not seeing much female representation in the makerspace, given that it is in the Faculty of Engineering, which still has more male than female students. Being a person of colour was also a notable difference for them. In addition, Zoe and Maggie talked about not being fluent in French as a barrier for participating in the community and communicating with French-speaking people. Since making is a social environment where people interact, they do not feel comfortable when they cannot communicate easily.

Acceptance as a distinct individual in engineering

All participants said they are different from other people in engineering. Maria and Zoe said it is primarily a gender difference, although there are also some ethnicity differences. Religion was also a factor for Zoe since she wears a hijab. Daniel and Hannah notice differences in skills and interests among their peers.

> *"I'm kind of just like focusing on one part of it, and you're focusing on another part, and we're kind of disinterested in each other's parts." — Hannah*

Maggie said she has a different way of approaching engineering to be functional with her ADHD. Max mainly saw differences between him and other people in engineering who are not makers. Liam cited personality differences, mainly between those who are introverted and those who are extraverted.

As with making, the participants said they can generally express their differences, but in some cases, it is not as easy. As Maria explained, engineering tends to be more close-minded, with less room to be unique, accepted and undoubted.

> *"Because you can be anyone, with any background in the making, and you also are welcome. But [in] engineering, you have to be from an engineering background who believes in everything in engineering to belong." — Maria*

Because of the female minority in engineering, both Hannah and Zoe explained that they feel an internal, and sometimes external, pressure to do well and be perceived as competent by others.

> *"I was like 'oh like you're one of the only girls in this mechanical engineering class, you really have to do well, improve yourself,' and I didn't like to ask people a lot of questions because I don't want to seem like the dumb girl who doesn't know." — Hannah*

> *"I spend a lot of mental energy, I think, on just making sure that people don't think I'm not good enough or competent enough." — Zoe*

Similarly, Maggie said she is "exceeding people's expectations" as a woman but that she is able to be involved because she is a social person. Maria also said some see her as "lesser of an engineering graduate" because she is not working as an engineer in a chemical plant. Zoe explained that the external pressure to be doing something in the field of engineering comes from Engineers Canada's 30 by 30 initiative (for 30% of newly licensed engineers to be women by 2030) (Engineers Canada, n.d.).

Maggie also addressed the stereotype that male students tend to study less but do well on exams, while female students are stereotypically very organized and go-getters. She said these stereotypes are reinforced by the way the course material in engineering is designed for males.

> *"That stereotype of guys just studying for exams and then acing it is because the course material is, like, designed for them to succeed in a sense — and it's irritating." — Maggie*

3.5.1.4. Survey scores

All participants were asked to complete the inclusion survey discussed in the quantitative part of this study. They were then asked to discuss how accurate they felt their scores were to give more context to the quantitative analysis previously conducted and determine how accurate the inclusion scores might be. They all felt the percentage generally represented how much they were feeling included in each community, although Maggie, Hannah and Zoe said the score for feeling included in engineering seemed a bit high compared with how they usually feel.

3.5.2. Discussion

Group membership is important because it gives people a sense of belonging, security, self-esteem and social identity (Van Prooijen et al., 2004). At the centre of inclusion lies the desire for relatedness or belonging, which is the "motivation to form and maintain strong and stable relationships with other people" (Jansen et al., 2014, p. 371) along with a desire to be unique or an individual, which is the "motivation to have a distinctive self-concept" (Jansen et al., 2014, p. 371), given that feelings of inclusion can be heightened when a unique individual is accepted by the group. These core elements were explored in the semi-structured interviews with seven participants. More specifically, belonging and uniqueness were looked at in the context of the making and engineering communities. The implications of the findings are discussed in the following sections to understand the reasons for feeling or not feeling included in the making and engineering groups.

3.5.2.1. Feeling included in the making community

The maker traits identified by the participants (creator, problem-solver and working on personal projects) correspond to the general maker description and traits found in the literature (Martin, 2015). The identity of a maker for each participant in this study varied slightly, but the broad definition was the same. Feelings of belonging to the making community were shown to be affected by how the participants connect and relate to this identity. This finding is supported by Martin (2015), who links the maker identity to the participants in the maker movement, implying that the makers who feel they belong will participate in the community. It stands to reason that the maker culture would be defined by its participants and their identities; however, the more the culture is able to adapt and evolve, the more diverse it can become. The general acceptance of new identities in the culture would also determine how open and inclusive the community tends to be. The community as a whole was perceived to be diverse, welcoming and helpful by the participants in this study, even if they do not feel included in it. This finding is in line with the documented characteristics of makerspaces (Tanenbaum et al., 2013; Taylor et al., 2016). The participants have an internal point of view, however, since they are not complete outsiders to the maker world, given that engineering students are not really outsiders to making, so it would be important to ensure that newcomers to making feel welcomed in the same way.

The participants gave some reasons they connect to the making identity beyond the maker traits identified above. They explained that their background and family traits contribute to their association and inclusion in making. If their family is generally handy and resourceful or their childhood experiences involved hands-on activities, they have grown up with making tendencies or have been more exposed to making, which makes them more comfortable in this environment. The hands-on (kinesthetic) personality is also an aspect of makers that was described as part of a person's background and learning preference, which affects whether that person will like making or not. Zoe explained that because her learning preference is not kinesthetic, she will never be a maker. The participants also explained that if their hobbies were making-related — that is, things that fit in the maker culture of hands-on, creative design projects — they would almost automatically say they would be included in the making community.

As much as the community is welcoming, some barriers to feeling included in or relating to the maker identity were identified. The revival of the maker movement in the early 2000s emerged with the computer industry and has been linked to technology and digital tools (Dougherty, 2012; Martin, 2015). This traditional technological making does not include textile or fibre craft practices (Rogers, 2017). These can be considered feminized skills that are not practised by the dominant maker community, which is largely male (Holbert, 2016). The creation of electronic textiles (e-textiles) using soft circuitry has been suggested as an avenue for integrating and encouraging women and queer and trans people in making (Betser et al., 2019; Rogers, 2017). This is reflected in the finding that two of the female participants, Maria and Hannah, said that although they sew and fabricate with textiles, they only partially consider themselves to be makers. Maggie indicated that she is simply not from a technological background, so it was a steep learning curve to come into the maker world and was a reason she did not feel included at first. The maker movement is widely advertised as having a low barrier to entry (Niaros et al., 2017; Rogers, 2017); however, the technology, including programming, is still a hurdle that should not be overlooked.

At least three of the female participants also expressed that there are gender biases against them in the community. They gave examples of times when others doubted their abilities, usually related to technology, and when they did not feel comfortable asking questions. As mentioned above, women are a minority group in the making community, which is reflected in the uOttawa makerspace, especially considering it is in the Faculty of Engineering, in which women are also a minority. This seemed almost normal to them in the sense that it was not a major contributing factor to their feelings of inclusion, although it is “irritating”, as Maggie puts it. When talking to the female participants, it is observed that they noticed societal influences, either general biases and perceptions or gender-specific interactions and differences. This indicates these biases are present enough to have made a lasting impression on them.

Most participants thought they were different in some ways from other people in the maker community but were not completely unique. They also thought they were able to express their differences freely because the community is diverse. This ability would seem to fulfil the need to have a distinctive self-concept and allow them to feel included.

The concept map in Figure 3 describes the aspects that affect feelings of inclusion in making discussed here. Belonging and uniqueness, the core elements of the theory of inclusion (Jansen et al., 2014), are linked to the three identified themes from this research (connecting with the making identity, participation and distinctiveness) and are characterized by the main factors in the figure. The direction of the relationships is determined from the interview analysis. Belonging is seen to be influenced more strongly by the connection to the identity and by factors such as personality, projects and ability to help from the conversations with the participants. Uniqueness is influenced by personal distinctiveness, with gender as a factor. Self-identity influences each theme and has an effect on feelings of inclusion in making. A result of feeling included in making for these students is the feeling of being empowered and better understanding engineering principles.

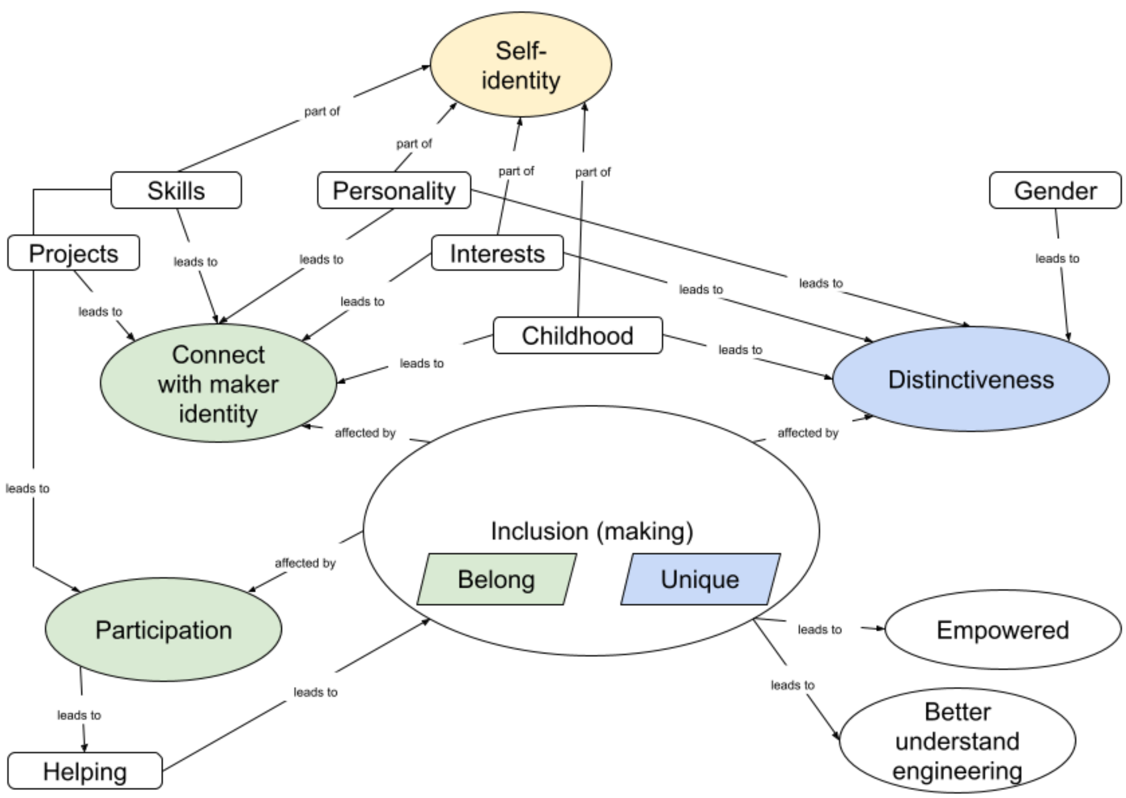

Figure 3. Concept map for feelings of inclusion in making

3.5.2.2. Feeling included in the engineering community

Although the definition of engineers and what it means to be an engineer varied between participants, most talked about engineering as a profession rather than a social identity. This is consistent with the literature on engineering identity, which sees engineering as something that people do, not who they are (Friedensen et al., 2018). The identity of an engineer is related not only to disciplines in STEM fields but also to the profession (Choe & Borrego, 2019). That professional identity has been connected to "competence in technology adoption, scientific thinking, and professional knowledge […] and as a way of thinking about using math, science, communication and problem-solving" (Friedensen et al., 2018, p. 3). This is again consistent with the participants who describe problem-solving and applying science principles as being engineering traits. They also say they are not yet engineers because they are not yet working in the industry and are not professional engineers, factors that lower their feelings of belonging to this group.

The professional identity definition corresponds to reasons that participants gave for feeling more or feeling less included in engineering. First, competence in technology, more specifically a lack of competence in programming, is something that made Maggie feel less connected than her peers to engineering. Second, competence in professional knowledge allowed Daniel to effectively communicate with his employers and make him feel like he belongs more to the profession. Maria said she identifies with the engineering mindset and her ability to solve problems, corresponding to competence in scientific thinking, which is how she would feel connected to engineering.

Some participants described the fact that their experience in engineering was not what it seemed from the outside. They described many stereotypes and impressions of engineering traits, of the way students study and of gender profiles. There was a distinction between these stereotypes and the reality of what they found once in the engineering program. Although they found some traits and behaviours to be true for some of the people they encountered, there was far more diversity than what they had initially imagined. This could have contributed to reduced feelings of belonging in the community stemming from not finding what they were expecting. Max also felt that engineering should be portrayed with more making components to it, since that is the side he feels more strongly connected to. Public stereotypes of engineers might not have presented a barrier to some students entering this field of study, given that many engineering students have a close relative, usually a parent, who is an engineer (Leslie et al., 1998).

The course subjects and engineering curriculum made up another element that was described as influencing how included the participants feel in engineering. Many people go into engineering because they enjoy and are good at math and physics (Leslie et al., 1998). However, others are attracted to a particular subject; some of the participants in this study wanted to learn about chemical, computer, biomedical mechanical or mechanical engineering specifically. Hannah explained that the courses were not what she had expected; she had trouble understanding how the information was applicable to real-world situations, and this was a major reason she switched out of engineering. Max explained that he thinks the classes are too theoretical without real-world application of that knowledge. He also said that first year was a lot of math without learning anything about the computers that he is interested in. Maggie and Hannah also said first year is mostly math and physics. In addition, Zoe felt that she was able to connect to engineering more in the second half of her undergraduate degree because the courses made more sense. These thoughts of not enjoying their first couple of years of study or seeing their importance lead to students having lower levels of feeling included in engineering.

Another factor shown to influence belonging is internal or external pressures on women to perform well and continue in the field of engineering. As in the making community, they face doubts about their abilities from peers or professionals and actively notice they are a minority in engineering, which contributes to lower feelings of inclusion.

The participants perceived less diversity of people in engineering. Although they still feel they can express their differences in engineering, it is more difficult than in making, with less room to be accepted. This view of the community could contribute to more people, particularly women and ethnic minorities, not feeling like they fully belong to engineering.

The concept map in Figure 4 describes aspects that affect feelings of inclusion in engineering discussed here. Again, belonging and uniqueness, the core elements of the theory of inclusion (Jansen et al., 2014), are linked to the three identified themes from this research (connecting with the engineering identity, participation and distinctiveness) and are characterized by the main factors in the figure. The direction of the relationships is determined from the interview analysis. Belonging is seen to be influenced more strongly by the connection to the engineering identity and by factors such as childhood experience, interests and the professional identity of a P.Eng from the conversations with the participants. Uniqueness is influenced by personal distinctiveness, with gender and ethnicity factors. Self-identity influences the identity and distinctiveness themes and has an effect on feelings inclusion in engineering.

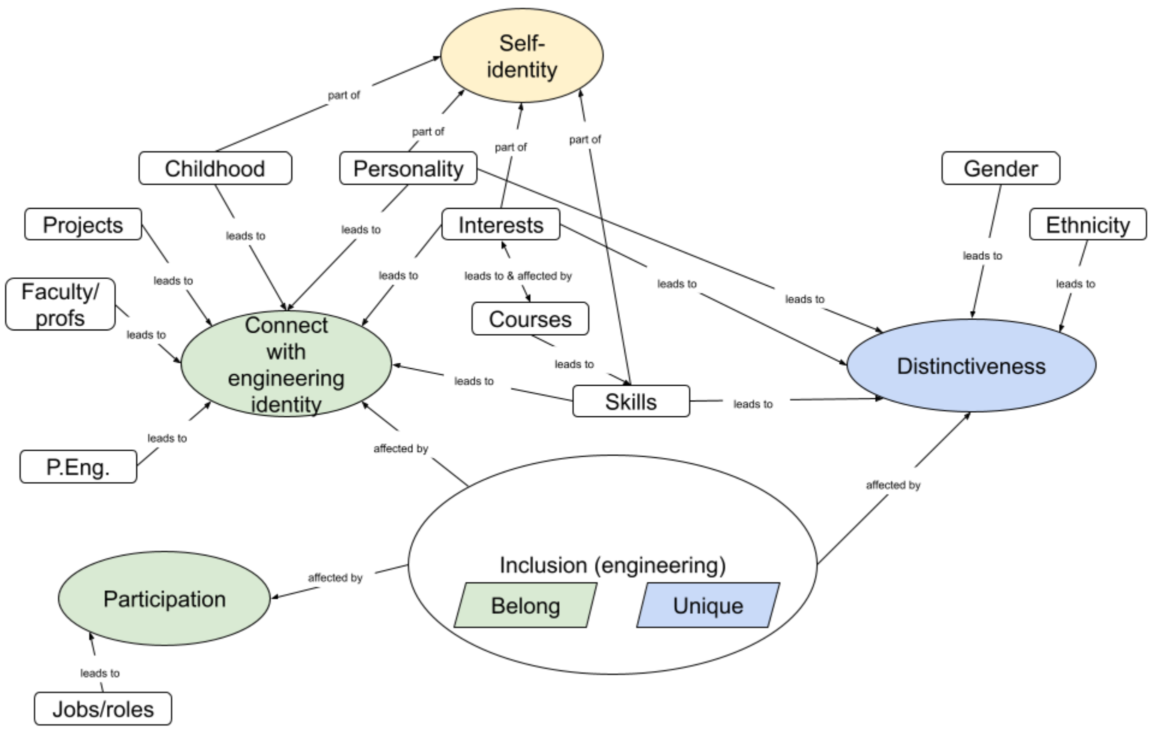

Figure 4. Concept map for feelings of inclusion in engineering

The concept maps for feelings of inclusion in making and engineering are similar. The differences relating to the theme of connecting with the identity show that engineering has more elements linked to the university experience (course of study and professors) and the profession (P.Eng.). Participation in making is also demonstrated as double-sided, where helping can boost a person's feelings of inclusion at the same time as the community is seen to include people who are helpful. In terms of distinctiveness, ethnicity was a factor discussed in engineering but not mentioned in the context of making. Finally, there was no clear result of feeling included in engineering; in making, on the other hand, people who feel included were seen to be empowered to build.

3.6. Limitations

The two studies in this chapter — the identification of baseline feelings of inclusion and the reasons for them — have limitations in regard to the number and diversity of participants. For the quantitative part, the number of post-course respondents is too low to be able to make any statistical conclusions based on the data. There are also not enough students in each program of study or year of study to make conclusive inferences based on these factors. For the qualitative part, ethnicities of the participants are not varied, and all the participants had making experience, so no “outsider” point of view was able to be compared. The results may not be comparable to participants from different makerspaces and different universities with a different context. With a higher number of and more diverse participants, more factors that affect the identified themes could also be discovered and could substantiate any possible conclusions that are proposed here more globally.

3.7. Conclusion

Anecdotally, it seems that integrating makerspaces into engineering design programs may help students to feel more included and more like engineers. The survey results were meant to collect a baseline score for feelings of inclusion for students in the uOttawa cornerstone engineering design courses. They were also used to indicate whether students felt more or less included in engineering and in making after taking a hands-on project-based learning course centered on client interaction and making principles. The inclusion scores for making and engineering were not significant for any of the gender, program of study, year of study or country of origin factors which indicates that students have no significant differences in levels of inclusion. On the other hand, some interesting baseline results revealed that female students seem to have lower scores, program of study has a variation in scores that needs to be examined further, and the students’ year of study has no impact on the results.

A deeper understanding of factors that affect feelings of inclusion in making and engineering was discovered through the semi-structured interviews. Connecting with people through the identity of the community and by interacting with others was shown to relate to feelings of inclusion. Personal background and traits in making are linked to the ability to make connections with others, as are professional identity and stereotypes in engineering. Participation is shown to bring value in each community but has certain barriers, such as technology proficiency and gender biases. The relevance and applicability of courses was also demonstrated to increase participation and feelings of inclusion. Distinctiveness was not found to be a major factor for inclusion in making, but being accepted for being distinct was seen to be more challenging in engineering.

It is also believed that three months is not long enough to see a change in feelings of inclusion, as there are no significant relationships with the differences in survey scores. The interviews seem to support this hypothesis, and more research needs to be done to examine the change over time of these inclusion levels. Uniqueness was not discussed in depth; however, it is an area for future development, given that when a unique individual is an accepted member in a group, the individual can have stronger feelings of inclusion. Effects of personality and ethnicity are also important considerations when looking at identity and need to be explored more in depth. More work needs to be done on inclusion in engineering design courses to understand students' feelings of inclusion and the effects those feelings have on their performance. Participants from different makerspaces and different universities would be needed to expand the scope and context of the research. Finally, engineering students who have no connection to making are needed for comparison, to provide a control group to test feelings of inclusion in engineering and the effects of making practices.

4. Chapter 4 - Effect of Personality Traits on Team Dynamics and Project Outcomes in Engineering Design

4.1.1. Objectives

Teamwork is a skill that employers search for when hiring people (Dym et al., 2005; Gomez Puente et al., 2013). In engineering design, diverse people come together to work on a project and must collaborate efficiently to get the job done. It is important to understand personality differences to be able to build effective teams. The skills of each member should complement the skills of others, and each member should push the team to innovate and produce better outputs. In engineering design in particular, where people are asked to come up with the best solution to a problem, often under pressure of a deadline (or a course grade), it is important to know how different people will work together to produce that optimal end product. For project managers and teachers, it is useful to know which people will work best together to give them the best experience possible and the opportunity to achieve the greatest results. This chapter explores the relationship between personality traits and the performance of teams and their members in an engineering design course. This is a continuation from the previous chapter to study student behaviour in the Faculty of Engineering, this time the effects of team dynamics and personality traits are considered.

Research was conducted in this study with the objective of examining the impact of team members' personalities, more specifically their Big Five personality traits (John & Srivastava, 1999), on team dynamics and team performance during a semester-long project in a project-based learning environment. Both individual and group performance were considered by collecting quantitative data to capture information from a large number of people and be able to make inferences (Borrego et al., 2009). The research question answered is the following: Are personality traits a predictor of team or individual success in a project-based design course?

This question is important because team-based projects are being used more and more in engineering (Gomez Puente et al., 2013), and so it is crucial to understand if personalities have the same effect in this context as in other reported ones. The results were expected to support the hypothesis that a person with higher openness, agreeableness and conscientiousness will perform better in the team and on the project. This would mean that these three traits would correlate with team and individual success in the course. A team with higher scores of the same three traits was also expected to perform better in the engineering design course, as would a team with more diverse members.

4.2. Methods

Data was collected through the courses' regular operation in fall 2018 and winter 2019 for the personality test, peer evaluation, team dynamics, year of study, project manager (PM) evaluation and project mark. The students were asked to share their grade point average (GPA), gender and team role voluntarily. Multiple regression analysis was conducted to determine if any of the factors listed could be shown to influence team performance and dynamics. Two sets of data were used to evaluate the students individually and as a group to answer the research question. Individual characteristics include personality scores, peer evaluation, adjusted project mark, PM evaluation, GPA and gender. Group characteristics are team dynamics, project mark and average team personality scores. The individual dataset includes 191 people: 152 male students and 39 female students. Of these, 102 students were in the first-year class and 89 in the second-year class. The group dataset includes 57 teams: 26 were first-year teams, and 31 were second-year teams.

4.3. Metrics

4.3.1. Personality test

ITP Metrics is a free assessment-based system with many different tools, including the Big Five personality test (O'Neill et al., 2018). The test was used to determine participants' scores on the five different personality factors. Participants answered 120 questions on a 5-point Likert scale relating to each of the traits: openness, conscientiousness, extraversion, agreeableness and neuroticism (emotionality). Each factor is characterized by various dimensions of personalities. Openness refers to curiosity, active imagination, aesthetic sensitivity and independent-mindedness; conscientiousness is self-discipline, determination, a will to achieve, being orderly and being responsible; extraversion refers to being talkative, sociable, assertive and energetic; agreeableness is the tendency to be cooperative, altruistic and trustful; and neuroticism is the tendency to experience negative affect, to not be calm and to be neurotic (Clinebell & Stecher, 2003; John &

Srivastava, 1999; Peeters et al., 2006). Each of the factors is rated on a positive scale, where 0 is low and 1 is the maximum. For this study, all scores in a team for a factor were averaged to be able to compare teams.

4.3.2. Peer evaluation and team dynamics

Another tool ITP Metrics offers is the peer feedback system, which provides “round-robin ratings of each member’s effectiveness in the team on five dimensions (communication; commitment; foundation of knowledge; skill and abilities; emphasising high standards; and focus)” (O’Neill et al., 2018, p. 1). The students evaluate themselves, each of their team members and the team itself and receive anonymous feedback to supplement their scores. Many software applications exist for peer feedback to facilitate data collection and analysis; CATME (Comprehensive Assessment for Team Member Effectiveness) is the most popular (O’Neill et al., 2018). Following a comparative study between CATME and ITP Metrics, Jamieson and Shaw (2018) confirmed that ITP Metrics is the preferred assessment platform based on time effectiveness for students and instructors, support for individual and team development, actionable feedback and effective integration into learning activities.

ITP Metrics uses a five-dimensional framework that is identical to CATME, with a few adapted terms (O’Neill et al., 2018). The effectiveness of using these five dimensions, as listed above, has been shown to be reliable and have valid evidence (Ohland et al., 2012). The purpose of the tool is to advance research into how peer feedback works, what influences the ratings and how to make successful teams, all of which make the tool perfect for application in this study. It is applicable and meaningful for this study because the teams here are working with task interdependence (O’Neill et al., 2018).

4.3.3. Project mark and PM mark

Project grade is the indicator of team performance. Over the course of the semester, students work on developing their prototypes and submit a deliverable almost weekly with their team to stay on track with the design process. Table 9 outlines all the deliverables, which add up to be 35% of the final grade for both courses.

Table 9. First- and second-year design course deliverables

	First-year course		**Second-year course**	
	Name	*Weight*	*Name*	*Weight*
Deliverable A	Team formation and contract	0.7%	Team formation and contract	0.7%
Deliverable B	Need identification	1.75%	Need identification and product specifications	1.75%
Deliverable C	Design criteria	2.8%	Conceptual design, project plan and feasibility study	3.5%
Deliverable D	Conceptual design	1.75%	Detailed design and prototype I	2.8%
Deliverable E	Project schedule and cost	2.8%	Project progress presentation	1.75%
Deliverable F	Prototype I and client feedback	3.5%	Business model	1.75%
Deliverable G	Prototype II and client feedback	4.2%	Prototype II and client feedback	3.5%
Deliverable H	Prototype III and client feedback	5.25%	Economics report	5.25%
Deliverable I	Design day presentation	5.25%	Design day presentation	5.25%
Deliverable J	Final presentation	3.5%	Intellectual property	1.75%
Deliverable K	Final report	3.5%	Final presentation	3.5%
Deliverable L	-	-	Final report	3.5%

The project mark that each team received in the fall 2018 and winter 2019 semesters was used in the group analysis as an indicator of how well the team performed together. An adjusted project grade was also calculated to determine the individual contribution by the student, using a personal factor applied to each person, which was taken from the peer evaluation results and ranged between 0.6 and 1.1. This method was used for consistency in this study because the actual adjusted project grade used at the end of both courses to weigh the grade given to students for their final mark is calculated slightly differently depending on the professor.

The project manager's evaluation is done by the TA and PM at the end of the semester and used as a supplement to the peer evaluation to ensure the groups are evaluating each other accurately. The students are graded individually using a five-item rubric with 5 points each for a total of 25 points, based on the work that the TA and PM see in the lab periods. The five items are teamwork, professionalism, communication, organization and discipline, and technical contribution. (See the table in Appendix B for the rubric.) This evaluation was also used to determine individual effort and contribution by the students.

4.3.4. Other metrics

Demographic information such as gender, program of study, year of study and country of origin was used to identify trends in the population of students. GPA has been used in other studies as an indicator of individual performance and was included here as well.

4.4. Results and discussion

The following sections outline the analysis and discussion of the individual and group factors and their effect on project outcomes like adjusted project mark, project mark and team dynamics in the design courses.

4.4.1. Individuals

4.4.1.1. Individual results

To start, a Spearman's rank-order correlation was run to measure the strength and direction of the relationship between two continuous variables (Lund Research, 2013) and assess the relationship between the individual performance variables. The results are shown in Table 10. This table demonstrates how each of the individual performance variables are related. They all show a significant relationship except for the adjusted project mark and GPA.

Table 10. Individual performance correlation

	Adjusted project mark	Peer evaluation	PM evaluation
Peer evaluation	0.191**	-	
PM evaluation	0.283**	0.297**	-
GPA	0.046	0.251*	0.431**

* statistically significant at p < 0.05 level; ** statistically significant at p < 0.01 level

A multiple regression was used to predict a continuous dependent variable based on multiple independent variables (Lund Research, 2013). It was run with 191 cases to predict the adjusted project grade from the Big Five traits. It demonstrated a significant relationship between the Big Five traits and the adjusted project mark.

Next, gender was added to the regression model, and the regression was run again. This second multiple regression was run to predict the adjusted project grade from the Big Five traits and gender.

The following tests were run to validate the assumptions for the multiple regression analysis. There was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values. There was independence of residuals, as assessed by a Durbin-Watson statistic of 1.384. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater than ±3 standard deviations, there were no leverage values greater than 0.2, and values for Cook's distance were above 1. The assumption of normality was met, as assessed by a P-P Plot. The first multiple regression model statistically significantly predicted adjusted project grade, $F(5, 185) = 2.502$, $p < 0.05$, $R^2 = 0.063$. The addition of gender led to a statistically significant increase in R^2 of 0.021, $F(6, 184) = 2.810$, $p < 0.05$. See Table 11 for full details on each regression model.

Table 11. Summary of multiple regression analysis — individual

	Model 1 (Big Five)		Model 2 (Big Five & gender)	
Variable	**B**	**β**	**B**	**β**
Constant	30.603		29.427	
Openness	0.677	0.021	0.634	0.020
Conscientiousness	2.959	0.095	2.898	0.093
Extraversion	-6.435	-0.203*	-6.893	-0.217*
Agreeableness	4.084	0.138	3.806	0.128
Neuroticism (Emotionality)	-1.759	-0.060	-2.493	-0.085
Gender			1.608	0.146*
R^2	0.063		0.084	
F	2.502*		2.810*	
ΔR^2	0.063		0.021	
ΔF	2.502*		4.134*	

* statistically significant at $p < 0.05$; B = unstandardized regression coefficient; β = standardized coefficient

Table 12 and Table 13 show correlations between the Big Five traits, separated by gender.

Table 12. Big Five trait correlations — male students

	Openness	**Conscientiousness**	**Extraversion**	**Agreeableness**
Conscientiousness	0.155	-		
Extraversion	0.333**	0.186*	-	
Agreeableness	0.469*	0.349**	0.260**	-
Neuroticism	-0.131	-0.432**	-0.313**	-0.172*

* statistically significant at $p < 0.05$ level; ** statistically significant at $p < 0.01$ level

Table 13. Big Five trait correlations — female students

	Openness	Conscientiousness	Extraversion	Agreeableness
Conscientiousness	-0.103	-		
Extraversion	0.357*	0.078	-	
Agreeableness	0.173	0.380*	0.185	-
Neuroticism	-0.123	-0.372*	-0.423**	-0.353*

* statistically significant at $p < 0.05$ level; ** statistically significant at $p < 0.01$ level

By graphing the adjusted project grade versus the personality traits by gender as well, the contrast between both genders can be observed. The relationship between extraversion and adjusted project grade is shown in Figure 5.

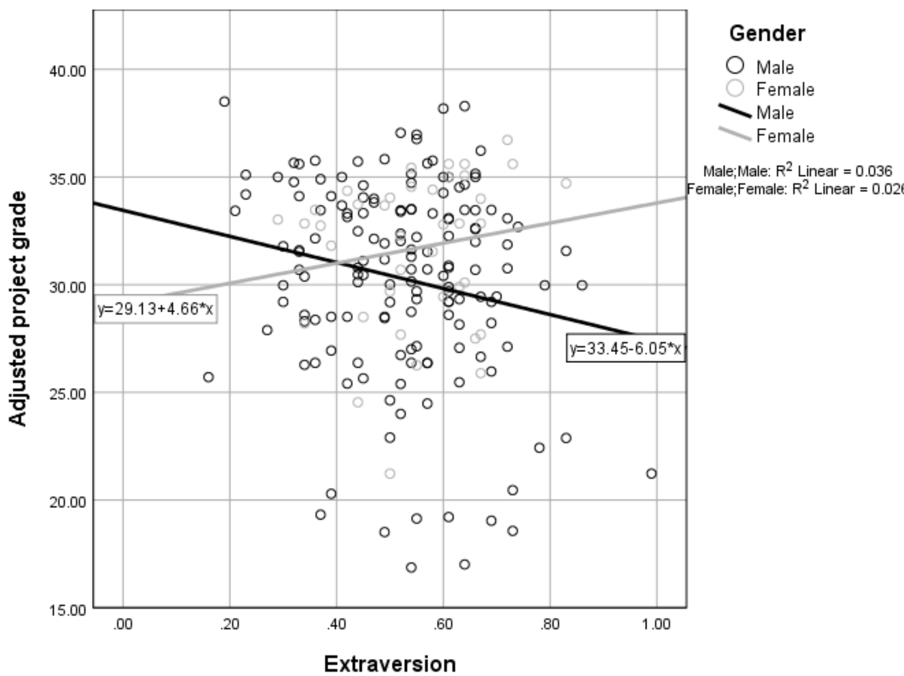

Figure 5. Relationship between extraversion and adjusted project mark, by gender

The mean ratings for the Big Five traits of the male and female students in the study are shown in Table 14. The distribution of data was similar for all traits and for both genders (similar standard deviations). A one-way analysis of variance (ANOVA) test was used to determine if there is a statistical significant difference between the means of independent groups (Lund Research, 2013). It was conducted for each trait and showed no significance between the means of each gender, with the lowest for neuroticism of $p = 0.131$.

Table 14. Mean and standard deviation of Big Five traits by gender

		Openness	Conscientiousness	Extraversion	Agreeableness	Neuroticism
Male	Mean	0.426	0.580	0.526	0.517	0.425
	Std. dev.	0.136	0.148	0.145	0.149	0.154
Female	Mean	0.443	0.573	0.549	0.542	0.470
	Std. dev.	0.157	0.127	0.123	0.157	0.137

Male students

Since gender had a significant effect in the previous regression model, another model was constructed to evaluate the relationship between the Big Five traits and the adjusted project grade for each gender separately. For the 152 male students, the following tests were run to validate the assumptions for the regression analysis. There was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values. There was independence of residuals, as assessed by a Durbin-Watson statistic of 1,445. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater than ±3 standard deviations, there were no leverage values greater than 0.2, and values for Cook's distance were above 1. The assumption of normality was met, as assessed by a P-P Plot. The full multiple regression model statistically significantly predicted adjusted project grade, $F(5, 146) = 4{,}108$, $p < 0.05$, $R^2 = 0.123$. Extraversion added statistically significantly to the prediction, and all added Big Five factors led to an increase in R^2 of 0.013. Regression coefficients and standardized coefficients can be found in Table 15.

Table 15. Summary of multiple regression analysis — male students

	Model 1 (O)		**Model 2 (OC)**		**Model 3 (OCE)**		**Model 4 (OCEA)**		**Model 5 (OCEAN)**	
Variable	**B**	**β**	**B**	**β**	**B**	**β**	**B**	**β**	**B**	**β**
Constant	29.101		26.757		29.420		28.741		31.830	
Openness	2.751	0.081	1.949	0.057	4.826	0.142	2.562	0.076	2.471	0.073
Conscientiousness			4.634	0.148	5.778	0.184*	4.394	0.140	2.786	0.089

Extraversion					-8.664	-0.27*	-9.051	- 0.28*	-10.08	- 0.32*
Agreeableness							5.122	0.164	5.294	0.,170
Neuroticism (Emotionality)									-3.924	-0.13
R^2	0.007		0.028		0.092		0.110		0.123	
F	0.993		2.135		4.977*		4.563*		4.108*	
ΔR^2	0.007		0.021		0.064		0.019		0.013	
ΔF	0.993		3.261		10.391*		3.110		2.144	

* statistically significant at $p < 0.05$; B = unstandardized regression coefficient; β = standardized coefficient

Given that openness was found to be poor predictor, having low coefficients and significance, it was taken out of the model, leaving the Big Five traits of conscientiousness, extraversion, agreeableness and neuroticism (CEAN). The new model was statistically significant, R^2 = 0.119, $F(4, 147)$ = 4.986, $p < 0.01$; adjusted R^2 = 0.096. In this model, extraversion and agreeableness were statistically significant predictors, -9.556, $p < 0.0005$ and 6,258, $p < 0.05$ respectively. In other words, 9.6% of the adjusted project grade for male students can be explained by their conscientiousness, extraversion, agreeableness and neuroticism.

Female students

The same analysis that was done with male students was also done with the 39 female students. However, none of the models were statistically significant, and none of the individual coefficients were significant in any model.

4.4.1.2. Discussion of individual contributions

Peer evaluation is widely used by researchers to understand interaction between members in a group (Oakley et al., 2004). Since the adjusted project mark, PM evaluation and GPA are all related, as seen in Table 10, it can be assumed that any of these other variables could be used to determine individual contributions to the project and team.

An important finding here is that GPA correlates to the peer and PM evaluations, indicating that people who perform generally well in school do just as well in a design class. This is supported by studies that have found GPA to be an indicator of team performance (Hacker, 2000). The reason GPA does not have a significant relationship with the adjusted project mark might stem from the fact that much of the adjusted project grade reflects the contributions of other teammates for the project deliverables, and these teammates might have brought down a grade that would normally be higher from an individual with a high GPA. Students with lower GPAs may also be influencing this result by being more engaged in a project-based course and getting a higher grade. The peer and PM evaluations are slightly skewed by perfect grades given to many students; if this were not the case, a stronger relationship between all these factors would be expected. Another reason for the weaker relationship is that peer and PM evaluation is a measure between group members that is relative to each member, while the adjusted project grade is relative to the entire class, so it has a different scale.

One variable, extraversion, was significant within the regression model of predicting the adjusted project grade against all the individual students' Big Five personality traits. The coefficients indicate that extraversion has a large negative relationship (-6.435) to the project grade, as indicated in Table 11. This result indicates that a more introverted person would have a significantly higher adjusted project grade and therefore have better team performance. Contrary to the hypothesis that higher conscientiousness and openness would yield better performance, here the coefficients are not significant. It is possible that these two factors have no significant effect on teamwork in this engineering design course. Ostafichuck & Naylor (2017) come to a similar conclusion when analyzing peer evaluation and domains in the Myers-Briggs Type Indicator, that only its "judging and perceiving" trait has a 1% significance on peer scores. Another possible reason for this result is that the adjusted project mark is not an accurate representation of personal effort or contribution by an individual in the team. This mark comes mainly from written reports and is scaled to take into consideration effort in the project, where the main design and prototyping progress and performance of the team may not be accurately captured. Another factor that could influence the project grades is the support offered by the teaching assistants and project managers, who offer guidance and help to all the teams to make sure none are in a critical state. Overall, most personality traits were not significant in the model, a finding that could be a result of too much diversity in the sample for a relationship to be noticed.

The second regression model in Table 11 adds gender to show the relationship between the Big Five personality traits and gender and the adjusted project grade. In this second model, extraversion and gender are significant and therefore have a significant effect on the adjusted project grade. As with the first model, extraversion is negatively correlated (-6.893). Gender is positively correlated (1.608). Therefore, people who are more introverted and women have better project grades and contribute more. Openness, conscientiousness, agreeableness and emotionality are all positively correlated and are not significant but still add value to the model and increase the R^2 (0.084). Again, this is contrary to the original hypothesis that high openness, agreeableness and conscientiousness scores would lead to a better performance. This second global model, which includes gender, has a higher proportion of variance (R^2) because gender does have an influence on the adjusted project grade, as observed in the regression models in Table 11. Women have been found to be “more ready” than men in first year to do engineering in context (Kilgore et al., 2007) and are more motivated by opportunities for social context (such as in this project-based learning environment) (Vaz et al., 2013). This could be the reason women are more likely than men to have a higher adjusted project grade in this case.

For men, extraversion correlates positively to openness, conscientiousness and agreeableness, and it correlates negatively to neuroticism, as seen in Table 12. This correlation was expected, but the negative relationship between extraversion and the adjusted project grade in the regression models was surprising. Further work needs to be done to properly understand the population and the results found here. It could be possible that the extraversion trait does not have the same effect on team performance as it does on individual performance. The male-only regression model shows that openness has a low coefficient and low significance level. A reason for this factor may be that this sample of engineers does not have a very high score for openness (maximum is 0.76 out of 1), as shown in Figure 6. Therefore, openness would not have a significant relationship with the project mark, since the data are skewed, and the openness trait is not indicative of the grade.

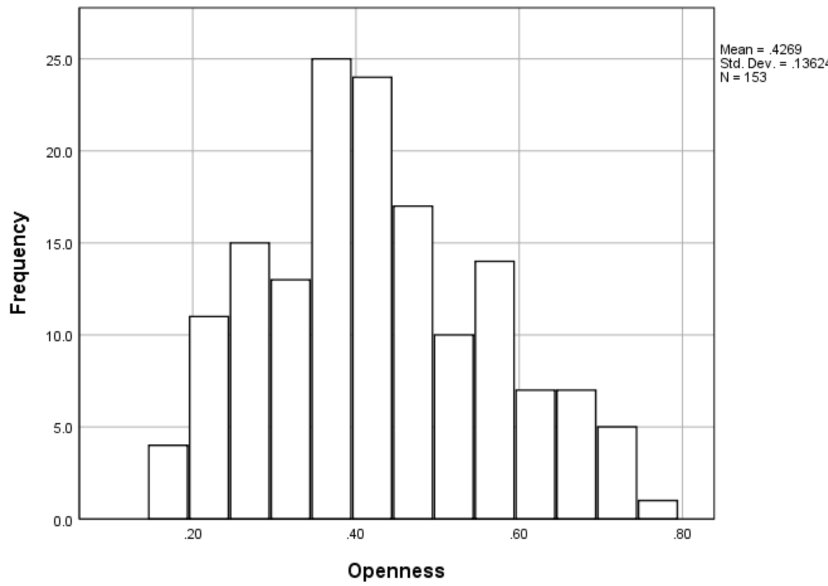

Figure 6. Openness histogram (male students)

The regression model containing only male data in Table 15 also had the surprising negative extraversion coefficient. However, the positive agreeableness coefficient was expected for teamwork, since positive interactions, sympathy and trust leads to a higher-performing team. Once openness was removed from the model, both extraversion and agreeableness were found to be significant, which was closer to what was expected.

The results from the female regression model were also unexpected. The women in this sample may have a higher diversity, or there might simply not be enough data to be able to find a statistically significant relationship. Even though the means of the Big Five traits are similar and not significantly different between men and women, as seen in Table 14, there is the opposite relationship between the personality traits and the adjusted project grade (as Figure 5 demonstrates). Women may also perceive personality traits differently from men. In comparing the Big Five factor correlations of each gender in Table 12 and Table 13, it is evident that the relationships are different between genders. There are eight significant correlations between factors for male students but only five for female students. This result is surprising and may lead to the conclusion that female behaviour within engineering teams is different from male behaviour, but more research needs to be conducted in this area.

4.4.2. Groups

4.4.2.1. Group results

A Pearson's product-moment correlation was used to determine the strength and direction of a linear relationship between two continuous variables (Lund Research, 2013). It was run to assess the relationship between the team factors — project mark and team dynamics (as measured by the ITP Metrics evaluations) — and the average team personality traits. The correlations are shown in

Table 16. Based on the significant correlation between project mark and conscientiousness, a linear regression model was conducted between the two continuous variables to predict the value of the dependent variable based on the value of the independent variable and assess the linear relationship (Lund Research, 2013).

Table 16. Average group factor correlations

	Project mark	Team dynamics	Avg O	Avg C	Avg E	Avg A
Team dynamics	0.086	-				
Average O	-0.053	0.106	-			
Average C	0.320*	0.111	0.312*	-		
Average E	0.027	0.021	0.336*	0.348**	-	
Average A	0.058	0.247	0.302*	0.405**	0.375**	-
Average N	-0.191	-0.006	-0.081	-0.557**	-0.424**	-0.254

* statistically significant at $p < 0.05$ level; ** statistically significant at $p < 0.01$ level

The linear regression was run with 57 observations to understand the effect of the average team conscientiousness on the project mark. To assess linearity, a scatterplot of project mark against average conscientiousness was created with a superimposed regression line. Visual inspection of these two plots indicated a linear relationship between the variables. There was homoscedasticity and normality of the residuals.

The prediction equation was the following: project mark = 25.47 + 8.45*AvgC. Average team conscientiousness statistically significantly predicted project mark, $F(1, 55) = 6.262, p <$

0.05, accounting for 10.2% of the variation in project mark with adjusted $R2$ = 8.6%. In other words, 8.6% of the project grades can be explained by average team conscientiousness scores.

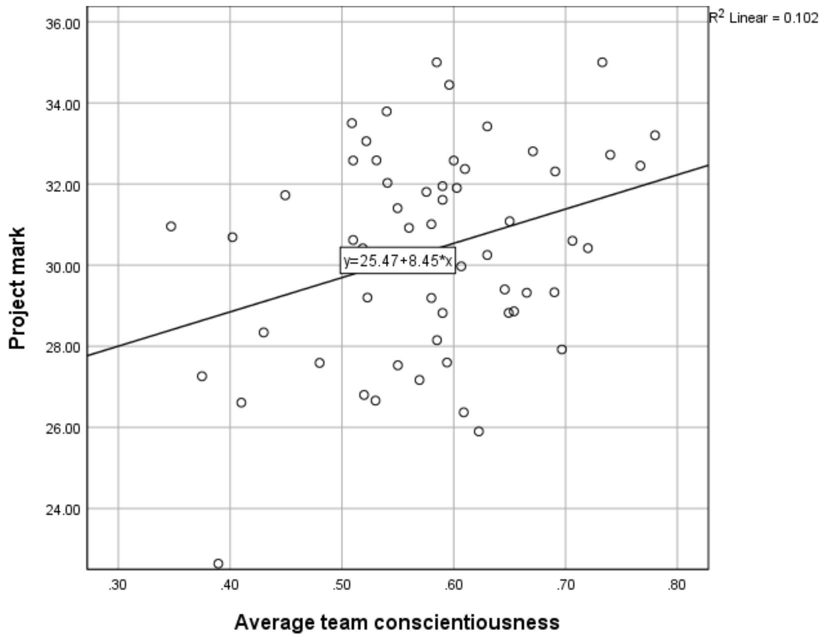

Figure 7. Relationship between average team conscientiousness and project mark

A Spearman's rank-order correlation was run to assess the relationship between the project mark, team dynamics and variance of the group personality factors. It was done with 53 of the 57 teams because the personality variance of a few of the groups were outliers. The results are shown in Table 17. None of the factors are significant with project mark or team dynamics; however, the significance level of openness variance is 0.051 with project mark and 0.058 with team dynamics. The results are graphed in Figure 8. Openness variance accounts for 3.4% of the project mark and 6.6% of team dynamics.

Table 17. Variance of group factor correlations

	Project mark	Team dynamics	Var O	Var C	Var E	Var A
Team dynamics	0.159	-				
Variance O	0.272	0.269	-			

Variance C	-0.076	-0.011	0.008	-		
Variance E	0.002	-0.019	0.064	-0.110	-	
Variance A	-0.047	0.050	0.462**	0.158	0.022	-
Variance N	-0.148	-0.185	-0.022	0.201	0.007	-0.025

* statistically significant at p < 0.05 level; ** statistically significant at p < 0.01 level

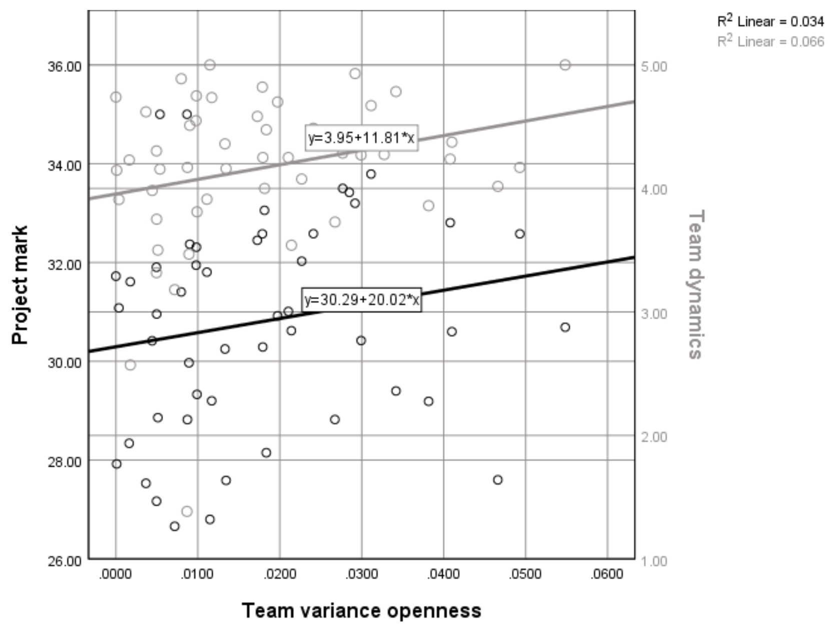

Figure 8. Relationship between variance of team openness and project mark, team dynamics

A Spearman's rank-order correlation was run to assess the relationship between the averages and variances of the group personality factors. The results are shown in Table 18.

Table 18. Average and variance of group factor correlations

	Avg O	**Avg C**	**Avg E**	**Avg A**	**Avg N**
Variance O	0.110	0.041	0.082	-0.022	0.027
Variance C	0.067	-0.309*	0.140	0.058	0.057
Variance E	-0.017	0.076	0.011	-0.110	0.066
Variance A	-0.080	-0.034	-0.117	-0.293*	0.156
Variance N	-0.095	-0.160	-0.092	-0.077	0.085

* statistically significant at p < 0.05 level

4.4.2.2. Discussion of group performance

The group conscientiousness result demonstrates that the grade for the design project can be explained in part by the average conscientiousness of the team, a finding that supports the hypothesis that higher openness, agreeableness and conscientiousness would lead to better performance. O'Neill & Allen (2011) came to the same conclusion that team-level conscientiousness predicts team performance. It can be reasoned that people who are more achievement-striving, organized and task focused will have a better team performance (Hua, 2013; O'Neill & Allen, 2011). This relationship can be seen in Figure 7. The significant negative correlation between the average and the variance of the conscientiousness of a group, seen in Table 18, also indicates that teams with a low conscientiousness variation have a higher total conscientiousness in this sample. Therefore, higher project marks are achieved by teams with members who are all relatively conscientious. This homogeneous trait leads to all members taking a similar level of responsibility and performing effectively together (Neuman et al., 1999).

Bivariate correlations and regression models have been calculated with the variance between a personality factor for team members in a group. Diversity of the different personality traits shows no significant effect on project mark and team dynamics in Table 17. The graph in Figure 8, however, shows that a variance of openness in a team has some effect on the project grade and team dynamics. This result is again surprising, since the hypothesis was that a more diverse team would perform better. However, the results agree with Neuman, Wagner and Christiansen (1999, p. 32): "certain traits may enhance performance when the team is homogenous, whereas other traits may enhance performance when the team is diverse." Since this sample of students has already been shown to have low openness, teams that have a member with higher openness would have the high variance in this trait. These teams would seem to do better on the project and get along better. The reason the results do not show any relationship between diversity in personality and performance might be a result of not having groups that are very different (in factors other than personality), as people tend to pick team members who they know or are like themselves. The undergraduate student population in engineering is also not terribly diverse (Busch-Vishniac & Jarosz, 2004). Other racial, cultural or socio-economic factors may have a larger impact on teamwork than different personality traits, by providing more varied perspectives and experiences.

More research in this area needs to be conducted to better understand the effects of personality diversity as opposed to racial, cultural and socio-economic diversity in an engineering design team.

4.4.3. Limitations

This study has the limitation that the results can be applied only to the particular job of engineering design or something that requires similar skills. Jobs or tasks with different task structures and organizational environments would favour different personality profiles. Results may also differ in other universities because the student population of engineers in different geographic locations might have different personality profiles. Indeed, students who have chosen a particular university might have similar (or different) personality profiles.

4.5. Conclusion

Since design is at the core of engineering, and teams are generally needed to accomplish design tasks, teamwork is an important skill to learn. A project-based learning environment is a great place for that exposure. Understanding the effect of the different aspects of personality enables better prediction of team success and better team formation procedures for instructor-assigned teams. Team selection can be based on many factors, but it is often unclear which ones are best. This study shows the relationship between the Big Five personality traits as well as gender and project grades in project-based engineering design courses. In terms of personality traits, openness, which can influence performance factors, was found to be low in this sample. This study found there is a difference in personality traits by gender, because 9.6% of the adjusted project grade for male students can be explained by their conscientiousness, extraversion, agreeableness and neuroticism (CEAN) personality traits, but none of the grade for female students can be explained by these traits. Overall, however, 8.6% of the project grades can also be explained by average team conscientiousness scores. Finally, personality diversity had no significant relationship in this sample to team or project outcomes.

This study also found a positive significant relationship between peer evaluation, PM evaluation and the adjusted project mark, indicating that any of these other variables could be used to determine individual contributions to the project and team. It also found that GPA correlates to peer and PM evaluations, indicating that people who perform generally well in school do just as well in a design class.

Further work is suggested to explore the effect of personality traits on design project success to understand how results may vary depending on gender. It would also be interesting to know if a low openness score is common across many departments or many institutions. Lastly, team racial, cultural and socio-economic diversity should be studied in addition to personality diversity to provide a more global understanding of the effect of diverse groups in engineering design.

5. Chapter 5 - Effect of Personality Traits and Project-Based Learning on Inclusion

5.1. Objectives

Personality traits dictate many behaviours, characteristics and feelings (John & Srivastava, 1999). They are important to take into consideration when looking at factors that may influence feelings of inclusion in a group, since the need to belong is a fundamental personality process (Dewall et al., 2011). At the same time, students' grades can be an indicator of their motivation and personal effort in a course (Hacker, 2000), which in turn may affect their feelings of belonging in their program of study. The research in this chapter combines the previous two chapters to study different effects on student perception and behaviour. It again explores students' feelings of inclusion in the University of Ottawa's Faculty of Engineering and in its maker community, this time the effects of personality traits, peer evaluation and grades are studied.

Research was conducted with the objective of studying the relationship between students' Big Five personality traits, individual project grades, peer evaluations and feelings of inclusion in the context of a semester-long project in a project-based learning environment. In brief, this research evaluates inclusion in the making and engineering communities. Collecting quantitative data to capture information from a large number of people allows for the consideration of individual traits, performance and feelings of inclusion and in order to make inferences (Borrego et al., 2009). In this way, the following research question aims to be answered: Do personality traits and individual success influence students' feelings of inclusion in a project-based design course?

5.2. Methods

Inclusion data collected in the beginning and at the end of the semester via online surveys was used to assess students' feelings of inclusion in the course. Personality, gender and project data (peer evaluation and adjusted project grade) were used as independent factors in this study and were collected as part of the normal operation of the courses. Linear correlation and regression analyses were conducted to determine if any of the factors could influence inclusion levels, either the baseline scores, post-semester scores or the difference between both. The dataset includes 190 people: 141 men, 46 women and 3 others. There were 129 students in the first-year class and 56 in the second-year class.

5.3. Metrics

See Section 3.3 for the data on feelings of inclusion collected via online surveys using the two inclusion scales. See Section 4.3 for the data on personality, gender, peer evaluation and adjusted project grade. The personality data and peer evaluation were collected from the ITP Metrics assessments. The adjusted project grade was calculated from the team project grade for the term with a personal factor from the peer evaluation results.

5.4. Results and discussion

The following sections analyze and discuss the effects of gender, the Big Five personality traits and project factors on feelings of inclusion in the making and engineering communities. The effects of gender are described first, since gender was found to be a significant factor for feelings of inclusion in Chapter 3.

5.4.1. Gender

Descriptive statistics for each inclusion metric — baseline, post-course and delta (the difference between them) — were generated, split by gender. A Kruskal-Wallis test — a non-parametric test to determine if there is a significant difference between two independent groups (Lund Research, 2013) — was conducted to determine if the difference in the delta inclusion scores, as shown in Table 19, was significant.

The distributions of delta scores for feelings of inclusion in the making community were similar for all groups, as assessed by visual inspection of a boxplot. Median delta scores were not statistically significantly different between groups, $\chi2(1) = 1.347$, $p = 0.178$. Similarly, scores for feelings of inclusion in engineering were not statistically significantly different between groups, $\chi2(1) = 0.284$, $p = 0.776$.

Table 19. Feelings of inclusion by gender

	Gender	N	Mean score: maker	Std. dev.: maker	Mean score: eng.	Std. dev.: eng.
Baseline	Male	141	76.03	10.91	76.29	10.95
	Female	45	74.52	12.29	74.45	13.20
Post-course	Male	54	76.60	12.20	77.68	11.46
	Female	15	80.17	9.72	80.55	12.83
Delta	Male	54	0.77	13.14	1.76	11.89
	Female	15	5.86	10.82	5.68	14.34

Note: See Appendix A for surveys used to determine scores for feelings of inclusion. Scores are out of 100.

Although these differences are not significant, they demonstrate a difference in feelings of inclusion or behaviour between genders, even if it is a small difference. This can be more easily be seen in the Figure 9 histograms, where the distribution of female students leans in the positive range, while male students are more centered around 0, indicating female students tended to feel more included as the course progressed.

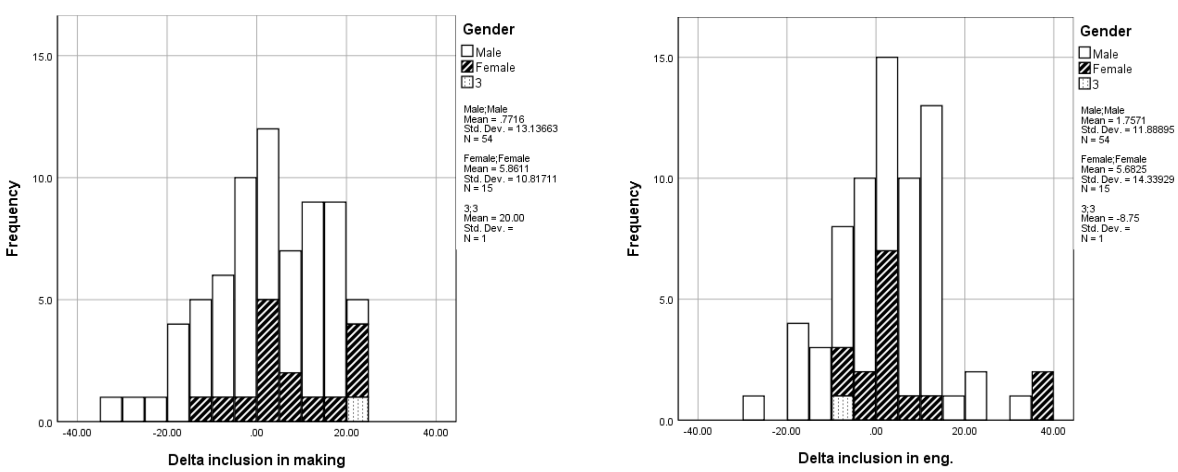

Figure 9. Distribution of change in feelings of inclusion in making (left) and engineering (right), by gender

5.4.2. Personality factors

The five factors in the Revised NEO Personality Inventory (NEO PI-R) are openness, conscientiousness, extraversion, agreeableness and neuroticism, or OCEAN (Clinebell & Stecher, 2003; John & Srivastava, 1999). A person can range from high to low on a scale for each factor.

5.4.2.1. Personality factor results

A Spearman's rank-order correlation was run to measure the strength and direction of the relationship between two continuous variables (Lund Research, 2013) and assess the personality trait and inclusion variables. The results are shown in Table 20, which demonstrates how the inclusion variables are related to the personality variables. The students' baseline feelings of inclusion were measured using 144 observations, and the post-course and difference scores were measured using 59 observations. The extraversion and neuroticism traits show a significant relationship with the pre-semester inclusion scores and with the difference in feelings of inclusion in engineering.

Table 20. Correlation between personality traits and feelings of inclusion

	O	**C**	**E**	**A**	**N**
Base: Maker	0.108	0.024	0.402**	0.013	-0.257**
Post: Maker	0.009	0.170	0.008	0.058	0.021
Delta: Maker	0.196	0.124	-0.196	0.095	0.096
Base: Eng.	0.064	0.107	0.379**	0.030	-0.276**
Post: Eng.	-0.049	0.099	-0.060	0.022	0.108
Delta: Eng.	0.201	-0.053	-0.281*	0.006	0.258*

* statistically significant at $p < 0.05$ level; ** statistically significant at $p < 0.01$ level

Based on the significant correlation between the baseline inclusion scores and extraversion and neuroticism, a regression model was run to assess the linear relationship between two continuous variables to predict the value of the dependent variable based on the value of the independent one (Lund Research, 2013). It was conducted with 144 observations to predict the baseline inclusion score for making from neuroticism. The results showed a significant relationship exists between neuroticism and baseline feelings of inclusion in making. (See Table 21.)

Next, extraversion was added to the regression model, and the regression was run again. This second multiple regression, therefore, was run to predict the baseline scores for feelings of inclusion in making from the two Big Five traits — neuroticism and extraversion.

The following tests were run to validate the assumptions for the multiple regression analysis. There was linearity, as assessed by partial regression plots and a plot of studentized residuals against the predicted values. There was independence of residuals, as assessed by a Durbin-Watson statistic of 1.869. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater than ±3 standard deviations, there were no leverage values greater than 0.2, and values for Cook's distance were above 1. The assumption of normality was met, as assessed by a P-P Plot. The first multiple regression model statistically significantly predicted baseline inclusion in making, $F(1, 142) = 7.566$, $p = 0.007$, $R^2 = 0.051$. The addition of extraversion led to a statistically significant increase in R^2 of 0.081, $F(2, 141) = 13.154$, $p < 0.0005$.

The same analysis was done for the baseline scores for the students' feelings of inclusion in engineering. Very similar results were obtained with the first model, to predict the effect of neuroticism, $F(1, 142) = 11.449$, $p = 0.001$, $R^2 = 0.075$. The addition of extraversion led to a statistically significant increase in R^2 of 0.048, $F(2, 141) = 7.739$, $p = 0.006$. One outlier was kept in the analysis after determining that there were not any sufficiently different results. See Table 21 for details on each regression model.

Table 21. Summary of multiple regression analysis — baseline feelings of inclusion

	Making				**Engineering**			
	Model 1 (N)		**Model 2 (EN)**		**Model 1 (N)**		**Model 2 (EN)**	
Variable	**B**	**β**	**B**	**β**	**B**	**β**	**B**	**β**
Constant	83.054	-	64.594	-	84.908	-	70.045	-
Neuroticism	-16.056	-0.225*	-3.082	-0.043	-20.367	-0.273*	-9.920	-0.133
Extraversion			24.714	0.338*			19.899	0.260*
R^2	0.051		0.132		0.075		0.123	
F	7.566*		10.684*		11.449*		9.866*	

ΔR^2	0.051		0.081		0.075		0.048	
ΔF	7.566*		13.154*		11.449*		7.739*	

* statistically significant at $p < 0.01$; B = unstandardized regression coefficient; β = standardized coefficient

The scatterplots from Figure 10 to Figure 14 visually represent the data on the relationship between the personality traits of extraversion and neuroticism and feelings of inclusion in making and engineering, split by gender. The significance of each linear regression is shown in the legend of each graph (* statistically significant at $p < 0.05$ level; ** statistically significant at $p < 0.01$ level).

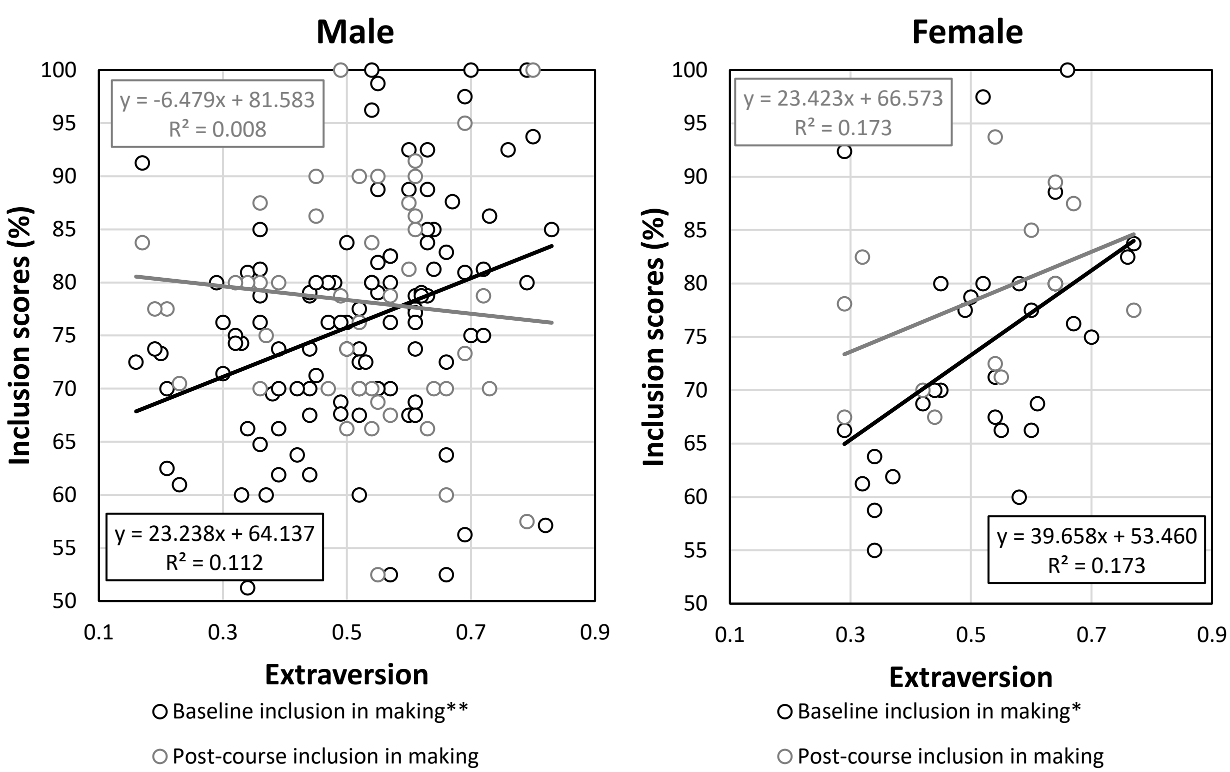

Figure 10. Relationship between extraversion and feelings of inclusion in making, by gender

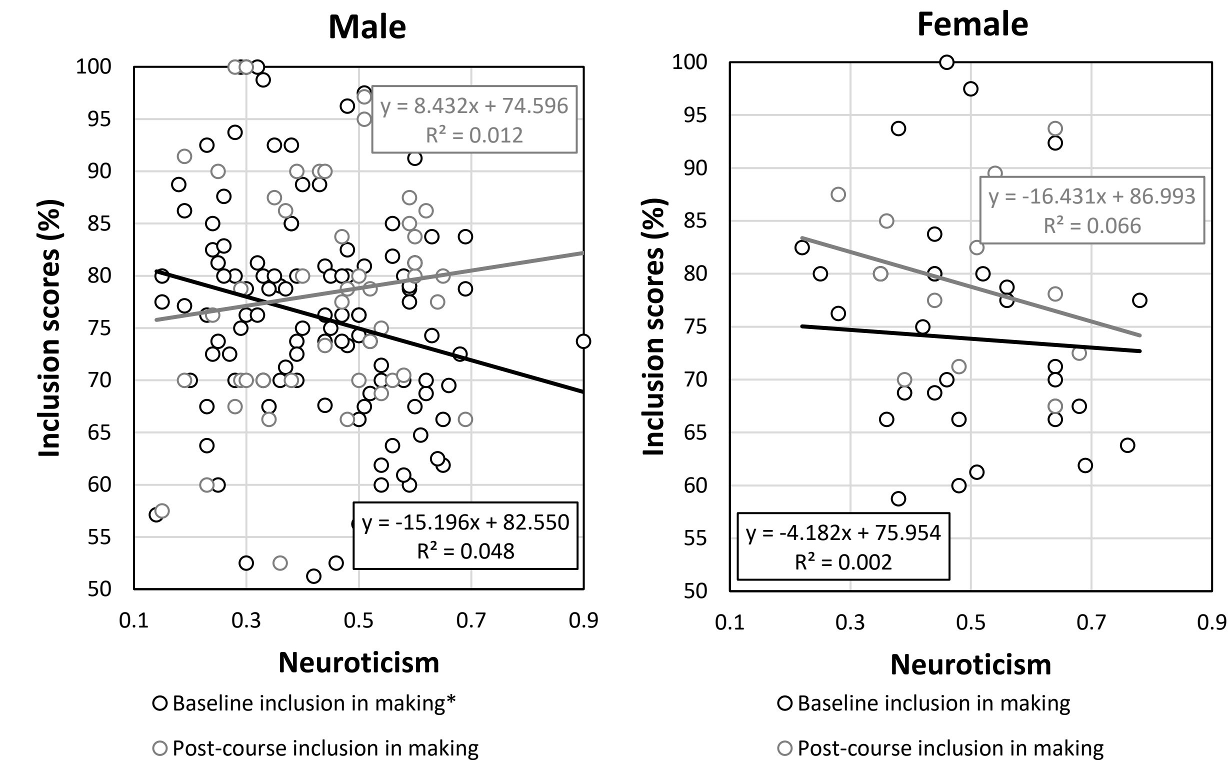

Figure 11. Relationship between neuroticism and feelings of inclusion in making, by gender

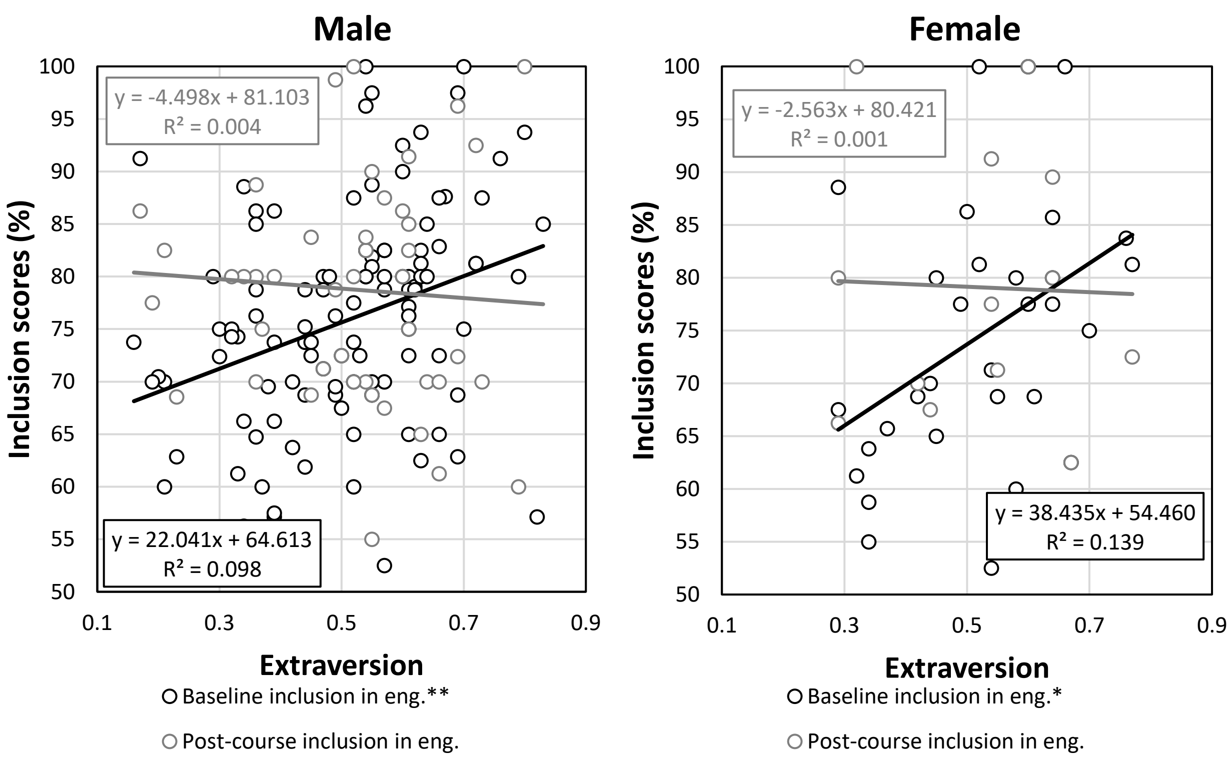

Figure 12. Relationship between extraversion and feelings of inclusion in engineering, by gender

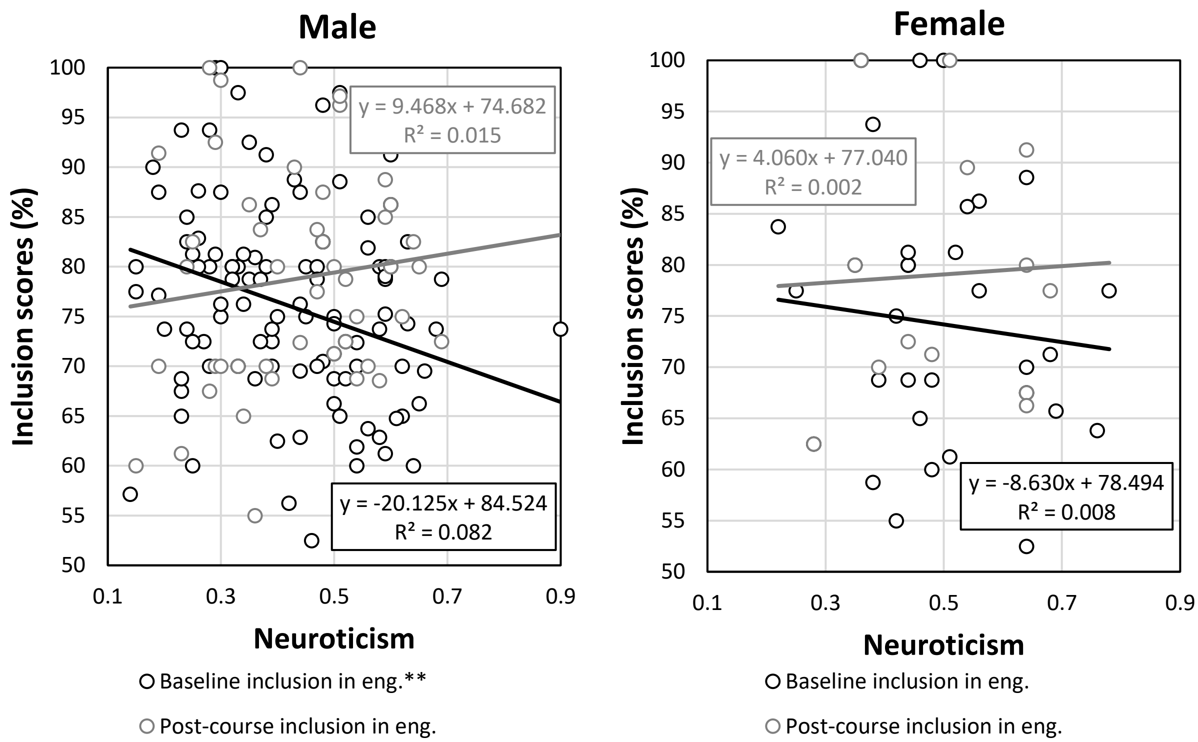

Figure 13. Relationship between neuroticism and feelings of inclusion in engineering, by gender

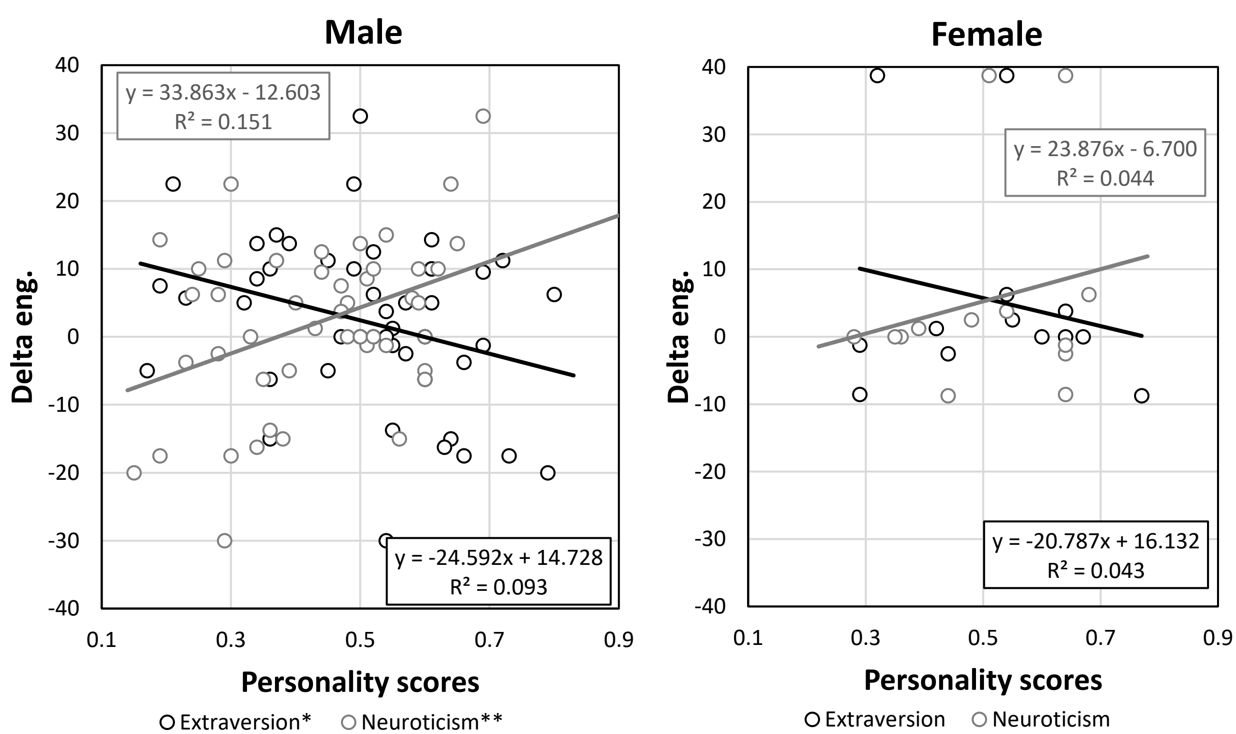

Figure 14. Relationship between personality traits of extraversion and neuroticism and change in feelings of inclusion in engineering, by gender

5.4.2.2. Personality factor discussion

Sheldon, Ryan, Rawsthorne & Ilardi (1997) find that personality traits vary depending on social roles. They hypothesize that only extraversion and neuroticism will have strong associations with well-being and authenticity; however, their results show that in roles where participants feel more authentic, they are more extraverted, agreeable, conscientious, open to experience and nonneurotic.

An important finding in this thesis is that extraversion and neuroticism have a significant correlation with some of the baseline inclusion variables. Given that authenticity is one of the subgroups of inclusion (Jansen et al., 2014), the results are supported by Sheldon, Ryan, Rawsthorne & Ilardi's study. The research for this thesis evaluated the students' personality traits only at the beginning of the semester. It might have been useful to measure them again at the end to be able to see if an increase in inclusion (feeling more authentic in the role) leads to changes in personality traits as students interact to their environment.

The regression model in Table 21 shows a relationship between the personality traits of extraversion and neuroticism and baseline inclusion scores in making and engineering. In the first model, neuroticism is found to be significant. In the second model, when extraversion is added, extraversion becomes the only significant factor. Neuroticism is negatively correlated with feelings of inclusion (-3.082 for making and -9.920 for engineering), and extraversion is positively correlated (24.714 for making and 19.899 for engineering). The finding that both models are statistically significant leads to the conclusion that both factors have an effect on the baseline scores, although extraversion has a much stronger effect. A more extraverted and less emotional person will feel more included in making and engineering before completing the cornerstone design course.

The graphs in Figure 10 to Figure 14 demonstrate the change in overall feelings of inclusion for each gender, from the beginning to the end of the semester, based on their personality traits of extraversion and neuroticism. It can be observed that if the slope of the fitted line is similar for each gender, there is a significant overall correlation for the variables in that graph, as indicated in Table 20. These significant results are the baseline scores for making and engineering (same as previously discussed) as well as the delta score for engineering. The following discussion will attempt to explain this.

When looking at the slope showing the relationship between extraversion and feelings of inclusion in making for men, the post-course result shows very low R^2 (0.008), as shown in Figure 10. This result suggests extraversion has no effect on feelings of inclusion in making by the end of the semester. Similarly, men with high scores for neuroticism are shown to have higher feelings of inclusion in making by the end of the semester, as demonstrated by the flatter slope ($R^2 = 0.012$). There is an overall mean increase of 0.77% in feelings of inclusion in making for all men. A reason for this change could be that the introverted men, described as unassertive and pessimistic, and emotional/neurotic men, described as insecure (Chiang, 2011), might have less confidence in their skills and abilities at the beginning of the course. This project-based course shows them that they are capable and therefore creates more of a balance in feelings of inclusion for all men by the end of the semester.

Although the shape of the extraversion slope for female students does not change over time, there is an increase in post-course scores for feelings of inclusion. There is an overall mean increase of 5.86% of feelings of inclusion in making for all women. The neuroticism slope is flatter for the baseline inclusion ($R^2 = 0.002$), suggesting neuroticism has less of an effect on inclusion at the beginning of the semester. However, less neurotic women have a higher inclusion score at the end ($R^2 = 0.066$). A reason for this could be that the women who score high on the emotional/neurotic scale could have been more influenced by a moderate or bad team dynamic experience in their groups or be more affected by the male-dominated environment, two factors that could lead them to have lower inclusion scores after the course. A compounding factor that could lead to lower feelings of inclusion could be that women are often less confident about their science and math skills (Leslie et al., 1998) and therefore choose, or are given, tasks related to organization, team management and report writing in the design group (Meadows & Sekaquaptewa, 2013). This lack of change over the semester could indicate that gender plays a role in assigning project tasks where men tend to take on hands-on making responsibilities. The assignment of roles along gender lines could be influenced by typical gender roles in society (such as the idea that a "handyman" is generally male) and reflected in the majority-male population of makers, but more research is needed in this area.

For both genders, the relationship between extraversion and engineering inclusion scores at the end of the course becomes almost flat in Figure 12, which indicates that by the end of the semester, extraversion has little effect on feelings of inclusion in engineering. The sign for the neuroticism slope changes for both genders over time, as shown in Figure 13; however, the R^2 for both post-course inclusion slopes is very low (0.015 for male students and 0.002 for female students). So, just like extraversion, neuroticism has little effect on feelings of inclusion in engineering at the end of the semester. One possible explanation for this result could be that the design course provides value to everyone equally and a realistic introduction to the world of engineering by bridging the science curriculum with engineering application (Busch-Vishniac & Jarosz, 2004) — unlike at many other universities, which do not introduce engineering design until the senior capstone course (Busch-Vishniac & Jarosz, 2004; Kilgore et al., 2007).

Figure 14 also shows that more introverted and emotional students have a higher increase in feelings of inclusion in engineering, which allows them to reach the same level as the more extraverted and not emotional students by the end of the semester. This result is supported by the idea that when people become more comfortable in a certain role, as an engineer in this case, their feelings of authenticity and therefore inclusion will increase (Sheldon et al., 1997).

5.4.3. Project factors

5.4.3.1. Project factor results

A Spearman's rank-order correlation was run to assess the relationship between the project and inclusion variables. The results are shown in Table 22, which demonstrates how the inclusion variables are related to the project variables. The data on baseline inclusion include 180 cases, and the post-course and difference scores include 70 cases. None of the factors show a significant relationship.

Table 22. Project and inclusion correlation

	Adjusted project grade	**Peer evaluation**
Base: Maker	-0.026	0.059
Post: Maker	0.153	0.076
Delta: Maker	0.199 (p = 0.099)	-0.034

Base: Eng.	0.039	0.069
Post: Eng.	0.102	0.074
Delta: Eng.	0.081	0.044

* statistically significant at $p < 0.05$ level; ** statistically significant at $p < 0.01$ level

Although none of the correlations in Table 22 were significant, the relationship between adjusted project marks and delta inclusion scores had the lowest value for significance in the table, approaching 0.05, and was therefore explored. A linear regression was run with 70 observations to understand the effect of the adjusted project mark on the delta inclusion score for making. To assess linearity, a scatterplot was created showing changes in feelings of inclusion in making against adjusted project grade with a superimposed regression line. Visual inspection of this plot indicated a linear relationship between the variables. There was homoscedasticity and normality of the residuals.

The prediction equation was the following: delta in feelings of inclusion in making = -17.54 + 0.651*adj.grade. Adjusted project grade statistically significantly predicted delta scores for inclusion in making, $F(1, 68) = 4.324$, $p = 0.041$, accounting for 6% of the variation in changes in scores for inclusion in making, with adjusted $R^2 = 4.6\%$. The scatterplot is shown in Figure 15 with an individual prediction interval of 95%.

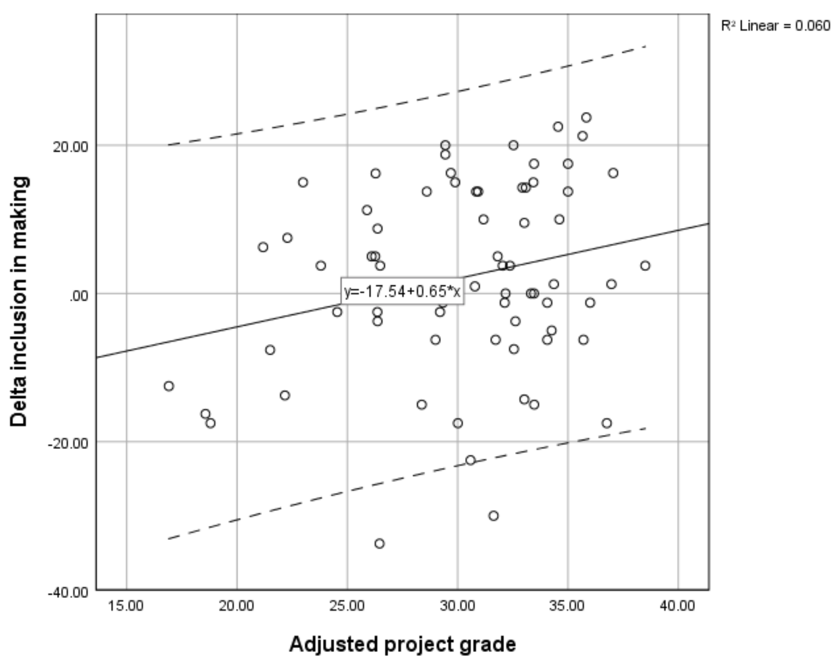

Figure 15. Relationship between adjusted project grade and changes in feelings of inclusion in making

Given that gender can be seen as having an influence on these global correlation results, these analyses were run separately by gender in Table 23. Those who identify as "other gender" were not included due to the low number of cases. Only the post-course score for feelings of inclusion in engineering showed a significant relationship with adjusted project grade.

Table 23. Project and inclusion correlation — by gender

	Adjusted project grade		Peer evaluation		Number of observations	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Base: Maker	-0.013	-0.002	0.016	0.175	135	43
Post: Maker	0.139	0.376	0.088	0.261	54	15
Delta: Maker	0.224	0.234	-0.008	0.109	54	15
Base: Eng.	0.070	-0.033	0.033	0.136	135	43
Post: Eng.	-0.023	0.615*	-0.011	0.342	54	15
Delta: Eng.	0.010	0.436	-0.010	0.402	54	15

* statistically significant at $p < 0.05$ level; ** statistically significant at $p < 0.01$ level

A linear regression was also run with 15 observations to understand the effect of adjusted project mark on the post-course score for women's feelings of inclusion in engineering. To assess linearity, a scatterplot was created showing changes in feelings of inclusion in making against adjusted project grade, with a superimposed regression line. Visual inspection of this plot indicated a linear relationship between the variables. There was homoscedasticity and normality of the residuals.

The prediction equation was the following: post-course score for female students' feelings of inclusion in engineering = 18.62 + 2.04*adj.grade. Adjusted project grade statistically significantly predicted post-course scores for feelings of inclusion in engineering for female students, $F(1, 13) = 6.337$, $p = 0.026$, accounting for 32.8% of the variation in post-course scores, with adjusted $R^2 = 27.6\%$. The scatterplot is shown in Figure 16, with an individual prediction interval of 95%.

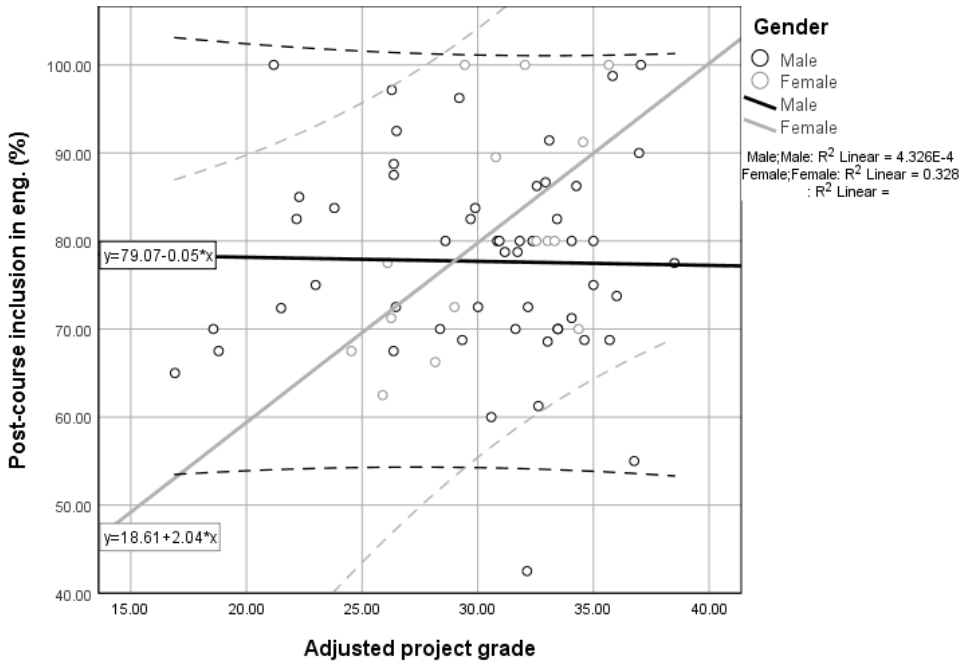

Figure 16. Relationship between adjusted project grade and post-course feelings of inclusion in engineering

5.4.3.2. Project factor discussion

The adjusted project grade correlations demonstrate that changes in feeling of inclusion in making and the post-course level of feelings inclusion in engineering (for female students) can be explained in part by these grades. Since the students are in a project-based environment where they must build prototypes, it seems reasonable that with better prototypes, or better grades, in conjunction with a higher personal effort from them (which leads to a higher adjusted project grade), the scores for feelings of inclusion in making will increase by a higher factor. This explains the 6% variance in changes in feelings of inclusion in making shown in Figure 15. A possible reason the correlation is not higher for making could be that the project grade represents mostly report writing for the deliverables and not making itself.

The linear regression done to explain the levels of inclusion in engineering at the end of the semester shows a much stronger relationship with the adjusted project grade, with a 32.8% R^2. The correlations between the baseline feelings of inclusion in engineering and the adjusted project grade for both male and female students are low (0.070 and -0.033 respectively). The male correlation did not change much (1.76% mean increase). However, post-course feelings of inclusion for female students with high grades increased by approximately 5–20%. This increase might be higher because some women may be more motivated by opportunities for social impact, and because women are reported to benefit more than men from project-based learning experiences (Tonso, 2006; Vaz et al., 2013). This greater engagement with the design process would lead to higher feelings of inclusion in engineering.

5.4.4. Limitations

This study is limited by the low number of post-course observations and therefore delta observations. Since female students are a minority, their numbers are even lower. The levels of feelings of inclusion in making may also be influenced by the specific project a student is working on and their interest in that project or how well they work with their teammates. Similar studies in other universities could find different results because other universities might have different activities and support for their students during the semester.

5.5. Conclusion

Personality influences a great deal of behaviour, emotions and interactions with others. This study investigated whether personality traits affect feelings of inclusion in engineering and in making communities in the context of a project-based learning environment with teamwork and real-life application of design and engineering skills. It shows a significant positive correlation of extraversion and a negative correlation of neuroticism with the baseline scores for feelings of inclusion in engineering. However, no correlation was found with these personality traits and feelings of inclusion in engineering by the end of the semester. These findings indicate that the students became more comfortable in their role as engineers, as the course brought value to students of both genders and with all types of traits, thereby equalizing differences between them.

Results differ depending on gender for feelings of inclusion in the making community. Baseline making inclusion correlates significantly with extraversion (positively) and neuroticism (negatively) for both genders combined. However, post-course scores of feelings of inclusion for male students no longer correlate with the two personality factors, whereas the same approximate slope is seen for female students between the start and end of the semester. In the context of making, the course therefore does not have the same equalizing effect as in engineering, indicating that gender might play a role in the responsibilities taken in a design team or women have different experiences with the making elements of the course.

Adjusted project grade was found to statistically significantly predict the change in scores of feelings of inclusion in making, explaining 6% of delta. Additionally, the adjusted project grade can explain 32.8% of the post-course scores for feelings of inclusion in engineering for female students, indicating that grades influence comfort levels in engineering school for women.

More work is suggested to investigate personality changes and their possible effects on feelings of inclusion levels over time to understand if personality changes as a person grows to feel more authentic in a particular role. Gender roles in design teams is also an area worth studying, to find out if there are predetermined biases that have an impact on feelings of inclusion and the retention of women in engineering.

6. Chapter 6 - Conclusion and Future Work

This thesis explored feelings of inclusion in making and engineering communities and identify factors that lead to people to feel more included. It also explored the reasons for participation in each community by people who already feel included. As well, the thesis explored factors that influence team performance in an engineering project-based design course and the relationship of team performance to feelings of inclusion. Chapters 3, 4 and 5 presented three studies on outcomes of cornerstone project-based courses in engineering design where a maker curriculum is included. The first was a mixed-methods study that provided baseline levels of feelings of inclusion of engineering students in the making and engineering communities, along with an analysis of factors that affect feelings of inclusion. The second explored the relationship between the Big Five personality traits, gender and project grades in the courses. The third compared the Big Five traits to the baseline and post-course inclusion scores in the same two communities. To conclude, this chapter outlines the main findings of the studies, makes recommendations for makerspaces and engineering programs, and suggests future research.

6.1. Findings

The quantitative study in Chapter 3 used an online survey to determine the baseline feelings of inclusion of students in a hands-on, client-centred cornerstone engineering design course at uOttawa. The same survey was administered at the end of the course to evaluate the impact of the intervention — that is, the course. None of the four factors — gender, program of study, year of study or country of origin — yielded a significant relationship with the scores for feelings of inclusion in making and engineering. Although there was no significant difference between the baseline and post-course scores, some interesting baseline tendencies were identified: female students seem to have lower scores than male students, program of study shows some unexplained variances in scores, and there is less variance in year of study than would have been expected.

The qualitative part of the study in Chapter 3 used semi-structured interviews to provide a deeper understanding of factors that influence inclusion in making and engineering. In both the making and engineering contexts, connecting with the identity, participation and distinctiveness were identified as themes that provide reasons for feeling or not feeling included. Connecting with the making identity was found to be mainly the result of personality, childhood and interest factors in addition to being able to work on self-directed projects that students had a particular interest in. Participation in making activities also contributes to feelings of inclusion in making, a finding that ties into research about makerspaces being supportive and helpful communities (Whyte, 2017); however, the ability to participate can be met with barriers such as a lack of technology proficiency. Distinctiveness was not an emphasized factor by the participants; therefore, it can be inferred that uniqueness does not pose much of a problem in this community. Connecting with the engineering identity was linked to interest, skills and professional factors. Participation also brings value in engineering but was mainly discussed through jobs or roles taken on by the participants. Distinctiveness was outlined as a challenge in this community in relation to gender and ethnicity. The interviews also identified the importance of sustained involvement for increasing levels of inclusion. Integrating making into the engineering curriculum was found to help some students feel more included and allow them to have a better understanding of engineering principles, although the findings cannot be generalized to the whole student population.

The study of the effects of teamwork and team performance in a project-based learning environment in Chapter 4 identified gender differences: the adjusted project grade for male students can be in part explained by their conscientiousness, extraversion and emotionality traits, but no factors were found to be significant for female students. Peer evaluation, PM grade and adjusted project mark all had positive significant relationships, indicating that any of these variables could be used to determine the individual contributions to the team project. Team factors were also investigated: the average conscientiousness score of a team was found to be a predictor of their project grade; however, personality diversity had no significant relationship with team or project outcomes.

The examination in Chapter 5 of personality traits as predictors of feelings of inclusion in making and engineering showed a correlation between baseline engineering inclusion scores and the personality traits of extraversion and emotionality. However, the post-semester scores show no significant relationship. This result could indicate that the course has an equalizing effect on both genders and personality types and makes the students more comfortable in their roles as engineers. On the other hand, the making scores vary depending on gender. It seems there is the same effect in making as in engineering for extraversion and emotionality for male students; however, female inclusion level correlations with extraversion and emotionality did not change. This is an indication that gender might affect which making responsibilities are taken on by members of a design team. Adjusted project grade was also found to be a significant predictor of the change in scores for all students' feelings of inclusion in making and for the female students' feelings of inclusion in engineering. This would reflect the fact that students who participate more in their project (making) feel more included and that female students feel more comfortable and confident in engineering when they get good grades.

In general, this research identified reasons for varying feelings of inclusion in the making and engineering communities, encapsulated by the three themes of connecting with identity, participation and distinctiveness. Gender differences were also observed. The female students' adjusted project grades did not correlate with their conscientiousness, extraversion and emotionality but were a predictor for post-course scores for feelings of inclusion in engineering. This indicates that the course might have helped female students become more comfortable in engineering when they got good grades and that personality traits did not influence this fact. On the other hand, extraversion and emotionality correlate with their baseline and post-course scores for feelings of inclusion in making, meaning the course did not have an equalizing effect on female students in terms of personality type and making ability. The opposite was found for male students: the project-based course showed them that they are capable and therefore created more of a balance in feelings of inclusion for all men by the end of the semester. For all students, team conscientiousness was a predictor of project grade. Extraversion and emotionality had little effect on feelings of inclusion in engineering by the end of the semester.

6.2. Implications for makerspaces and engineering programs

There are many different types of makerspaces with different tools and different audiences. Participants exposed to the academic makerspace integrated into the Faculty of Engineering mostly felt included in making, although there are a few aspects that could be improved.

First, although students do not need to have previous background in making, it is clear that such a background helps feelings of inclusion and lessens doubts about making abilities. It is important for people with no previous experience or knowledge of making to have a nonintimidating, safe way to be integrated into the space and taught without judgement. Learning to use the technology was also shown to be a significant hurdle. Makerspaces could consider implementing a more structured onboarding program to support those who are not as adventurous and confident about learning independently. Events or gatherings targeting underrepresented groups such as women, ethnic minorities and LGBTQ individuals could also help integrate people by creating an environment they are more comfortable in. Such efforts are already being made for elementary and high school girls, driven by the push to increase the number of women in STEM (Betser et al., 2019; Holbert, 2016) but could be implemented more globally for other underrepresented groups.

Second, the biases that female participants identified in other members of the community could be unconscious or even conscious biases stemming from the long history in society of gender-based roles, jobs and skills (Meadows & Sekaquaptewa, 2013). Makerspaces should consider acquiring and displaying more prominently tactile or "feminine" making elements — such as wearable technology or sewing — as well as elements from different cultures. A good example is Indigenous making and ways of knowing that are rarely included in makerspaces (Barajas-López & Bang, 2018). Adding more programming and software elements to a makerspace as well would diversify the participants even more. This would not only encourage participation of people interested in these types of making but also demonstrate to the other makers that these types are as important as the typical digital tools, like 3D printers, and hopefully start changing their point of view and biases.

The engineering community is seen as much more restrictive than the making community, because people who are not doing traditional engineering work or working towards obtaining their P.Eng. are not seen in the same light as those who are. Of course, people without their licences cannot be called professional engineers. However, the engineering culture has room to grow in terms of becoming more accepting of differences. The Faculty of Engineering, for example, could advertise avenues that are open to students after graduation other than jobs in industry, as a way to remove stigmas surrounding areas like education, entrepreneurship, management and trades. The world of engineering seen from the inside is much more complex than what is portrayed to the general public, which leads to misconceptions about what an engineer really is and really does. Although it would be difficult to demonstrate all the possibilities, some key elements like design, making, product life cycle and the ability to help people could excite students and accurately depict what engineers might do. Matusovich et al. (2020, p. 70) suggest that high school guidance counsellors and universities should collaborate to create “broad and inclusive definitions of engineering,” given that school personnel might have different conceptions of engineering and implicitly biased views.

The participants identified the fact that the first few years of their undergraduate degree program is mainly math and physics courses with no immediate application of that knowledge. The cornerstone engineering design courses offered by CEED attempts to address this concern; however, they are only two courses out of approximately 22 in the first two years of the undergraduate program at uOttawa. The courses help students see how to apply some knowledge from other courses, discover the nature of the design process in engineering and get exposed to the making realm. Other courses are also encouraged to include a project component where students, either individually or in teams, can directly apply and understand the knowledge of that subject. Project-based learning with real-world projects has been shown to help students develop engineering competence and become better innovators and problem-solvers (Choe & Borrego, 2019), which allows them to develop their engineering identity (Major & Kirn, 2017).

The impact of the CEED courses was shown to be marginal for Hannah and Leo. However, CEED participation had a transformative impact for Max and Maggie because of their prolonged exposure. Although the courses provide a good introduction to making and engineering design, long-term involvement is necessary to encourage leadership skills, community involvement and mentoring, which can increase feelings of inclusion. Zoe also showed that it is not possible, or necessary, to involve every student in making for them to feel included in the community.

Since the making community was shown to be more inclusive than the engineering community, there is merit to incorporating making elements into engineering, in addition to the advantages of project-based learning. The view that engineers build for a purpose and makers build for fun can be combined so that engineers have fun while they build and connect more to the project they are working on. The inclusive and helpful making mindset can also be shared beyond a design course to increase average levels of feelings of inclusion in the Faculty. Chapter 5 also demonstrates that engineering design courses can bring people of all personality types to the same level of inclusion in engineering and do the same for male students in making.

The results from all chapters show there are differing feelings of inclusion, personality trait tendencies and project grade predictors for male and female students. An engineering atmosphere that is often not welcoming to women (Marra et al., 2009) can exacerbate these differences by pushing away the women who feel different from the norm and are not included. For underrepresented groups to feel included, it is important for those who are designing and delivering engineering curriculum to actively think about different personality profiles, learning preferences and personal backgrounds, as well as messages that are being conveyed in the context of making.

Teamwork is another factor that should be looked at closely to give an optimal experience to all students. As Clinebell & Stecher (2003) suggest, roles in a team should be encouraged to be rotated so that everyone can have the same learning opportunities and chances to contribute in the same ways. This could help minimize the biases of gender roles in a team and lead to all students feeling the same levels of inclusion. Oakley et al.'s (2004) suggestion of not outnumbering people of underrepresented groups in a team should also be followed to ensure these people have the necessary confidence to fully participate in the team. Equally distributed conscientiousness levels in teams (ensuring none have low average levels of conscientiousness) could also allow each team to perform in a similar manner.

6.3. Future research

Previous studies have explored identity in engineering but have missed many important contributing factors, such as cultural ones (Friedensen et al., 2018). In addition, the whole construct of inclusion has not been looked at in engineering and has not been studied with a solid theoretical grounding in making. There are many possible directions for research; however, the findings in this thesis point to some specific gaps and areas for future research.

First, the baseline levels of feelings of inclusion presented some findings that were unexpected, and there was no significant change by the end of the course. This is a factor of interest that needs to be explored in more detail to understand the impact of not only one engineering design course but a few years in the engineering program. The findings from the interviews suggest uniqueness and other personal identity factors like personality and ethnicity need to be considered and probed in future research to understand their significance, especially when looking at impacts on underrepresented groups.

Second, personality changes due to evolving social roles need to be investigated in relation to inclusion to determine whether they change as a person grows to feel more authentic in a particular role. It would also be useful to study the effect of gender roles and biases in design teams to understand their effects on feelings of inclusion and the retention of women in engineering. As well, more work focused on gender differences is needed to understand the relationship between personality profiles, team dynamics and project success to help guide instructors when they assign students to teams. Demographic and personality diversity is also an area that should be explored to be able to better prepare students for work in diverse teams in the workforce.

Finally, participants from other institutions and makerspaces as well as outsiders from engineering and making groups would increase the generalization of the findings. Personality profiles across institutions could also be explored to investigate whether institutions are admitting particular types of students and how that affects the students' experiences through university.

7. References

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8. Appendix A

Perceived group inclusion scale (Jansen et al., 2014)

1. This group gives me the feeling that I belong.
2. This group gives me the feeling that I am part of this group.
3. This group gives me the feeling that I fit in.
4. This group treats me as an insider.
5. This group likes me.
6. This group appreciates me.
7. This group is pleased with me.
8. This group cares about me.
9. This group allows me to be authentic.
10. This group allows me to be who I am.
11. This group allows me to express my authentic self.
12. This group allows me to present myself the way I am.
13. This group encourages me to be authentic.
14. This group encourages me to be who I am.
15. This group encourages me to express my authentic self.
16. This group encourages me to present myself the way I am.

Psychological need-satisfaction scale (Sheldon & Bettencourt, 2002)

1. How included do you feel in this group?
2. To what extent do you feel well-integrated into this group?
3. To what extent do you feel a sense of belongingness within the group?
4. How much do you feel like you stand out within this group?
5. How much do you feel unique as you participate in the group?
6. How distinct and separate do you feel within this group?
7. How different is your group from other groups?
8. How much does this group seem to stand out, compared to other groups?
9. How much does this group seem unique, compared to other groups?
10. How free and choiceful do you feel as you participate in this group?
11. How much do you feel wholehearted (as opposed to feeling controlled or pressured) as you do things for this group?
12. To what extent does this group membership allow you to express your authentic self?
13. How close and connected do you feel with other members of the group?
14. How much of a sense of relatedness do you feel with the other members of the group?
15. To what extent do you feel a sense of personal friendship with the other group members?

Definitions of "maker" and "engineer," as provided to students in the survey:

Maker: "Activities focused on designing, building, modifying, and/or repurposing material objects, for playful or useful ends, oriented towards making a 'product' of some sort that can be used, interacted with, or demonstrated." (Martin, 2015, p. 31)

Engineer: "Engineering practice is not simply a problem solving process and specialized knowledge. It is the complex, thoughtful and intentional integration of these towards some meaningful end." (Sheppard et al., 2006, p. 435)

9. Appendix B

Table 24. TA and PM evaluation rubric

Criteria	Level 5 (5 pts)	Level 4 (3.75 pts)	Level 3 (2.5 pts)	Level 2 (1.25 pts)	Level 1 (0 pts)
Teamwork	Is essential to the team, always ensures good cohesion and cooperation.	Helps the team progress and usually cares about team dynamics.	Helps the team progress but does not always care about team dynamics.	Sometimes contributes but is not reliable.	Does not help the team, is not generally noticed.
Professionalism	Early to labs, is fully dedicated and drives things to closure, effective participation style, excellent focus. Owns responsibility for the project, is extremely reliable.	On time, dedicated to the work, participates effectively and good focus. Owns responsibility for their parts, is reliable.	Mostly on time, average dedication, participates regularly and ok focus. Usually responsible and reliable	Mostly late, does not care much about the project, participates occasionally, rarely focused. Not responsible or reliable.	Does not show up, rarely participates, is a detriment to the team.
Communication	Demonstrates excellent communication with teammates as well as PMs. Proactive to inform others of changes or modifications that concerned them. Asks questions when appropriate.	Good communication with teammates and PMs. Mostly proactive to inform others. Asks questions that are usually relevant.	Average communication with teammates and PMs. Sometimes proactive to inform others. Asks some questions but that are not always relevant.	Minimal communication with others. Does not ask questions when unsure.	Does not communicate or ask questions.
Organization and Discipline	Work is done extremely seriously and with precision. Ensures work is relevant and completed early.	Work is done seriously and is relevant, completed on time.	Some effort to make sure work is relevant and done properly. Sometimes completed late.	Minimal effort is put into the work completed. It is never done on time.	No effort to do any work.
Technical contribution	Does most of the work for the project. Has demonstrated excellent ability to learn and use technical skills.	Contributes more of work to the project than others. Has demonstrated ability to learn and use technical skills appropriately most of the time.	Contributes an equal amount to the project. Learns appropriate technical skills but doesn't always use them correctly.	Minimally contributes to the project. Attempts to learn some technical skills but does not use them or uses them incorrectly.	Does not contribute to the project. Does not learn any skills.

10. Appendix C

Final interview protocol

1. Can you tell me about yourself?
    a. Why are you in engineering?
2. Maker
    a. What is a maker?
    b. Are you a maker? Do you identify with that definition?
    c. Has this changed since you got to university? Since high school?
    d. Do you belong to this community? Why?
    e. Any other factors that affect how you feel in the community?
    f. Where do you position yourself in the community?
    g. Do you feel valued in the community?
    h. Do you see any differences between you and others in the community?
    i. Can you express those differences freely?
    j. Can you recall a situation where you felt differently?
    k. What would the community have to do to make you feel 100% included?
3. Engineer
    a. What is an engineer?
    b. Are you an engineer? Do you identify with that definition?
    c. Has this changed since you got to university? Since high school?
    d. Do you belong to this community? Why?
    e. Any other factors that affect how you feel in the community?
    f. Where do you position yourself in the community?
    g. Do you feel valued in the community?
    h. Do you see any differences between you and others in the community?
    i. Can you express those differences freely?
    j. Can you recall a situation where you felt differently?
    k. What would the community have to do to make you feel 100% included?
4. CEED
    a. Has the course/CEED had an effect on maker or engineering? Why?

5. Surveys
    a. (Share survey scores) Do you agree with this? Why?
6. Any final comments?

Table 25. Final codebook

Theme	Structural and initial codes			Description
Self-identity		Traits	Other	Personal traits or facts, eng. discipline
			Personality	Traits specifically relating to self personality
		Background		Family, environment, growing up
Identity	Maker	Traits		Personality, interests, mentality, demographic of makers
		Experience/abilities		Behavior, skills, abilities of makers
		Connection to maker		How/why they got involved with making
	Engineer	Traits		Personality, interests, mentality, demographic of engineers
		Experience/abilities		Behavior, skills, abilities of engineers
		Studies		What do engineers do/learn in school
		Connection to eng. subject		How/why they got involved with particular eng. subject
		Why studying eng.		How/why they got involved with engineering school
	Neither	Management/leadership		Other traits related to management or leadership
		General perceptions		General stereotypes or perceptions about maker/eng.
	Both	Maker-eng. relationship		Relationship between makers and engineers
Group membership	Maker	Group inclusion	Childhood	Inclusion with makers in relation to childhood, growing up (the past)
			Connect with people	Inclusion with makers in relation to community,

Theme	Structural and initial codes			Description
				working with people/in a team, connecting
			Gender/ethnicity	Inclusion with makers in relation to demographics
			Hobbies	Inclusion with makers in relation to hobbies
			Skills/job	Inclusion with makers in relation to skills, abilities, knowledge or job
			Ways of learning	Inclusion with makers in relation to learning methods (personality)
		Value/impact of participation		Impact and reasons for participating with makers
		Group affection		Valued by makers, by the community
		Group distinctiveness		Differences between makers and other groups
		Transition over time		Maker behavior, inclusion, perception changes over time
	Engineer/ engineering school	Group inclusion	Connect with people	Inclusion with engineers in relation to community, working with people/in a team, connecting, interests
			Courses	Inclusion with engineers in relation to courses, studies
			Gender/ethnicity	Inclusion with engineers in relation to demographics
			Skills/job	Inclusion with engineers in relation to skills, abilities, knowledge or job
			University/industry	Inclusion with engineers in relation to the faculty, university environment or industry/professional job
		Value/impact of participation		Impact and reasons for participating with engineers
		Group affection		Valued by engineers, by the community
		Group distinctiveness		Differences between engineers and other groups
		Transition over time		Engineer behavior, inclusion, perception changes over time

Theme	Structural and initial codes			Description
		Course/CEED impact		Impact of CEED on participant membership
		Social		Influence of social perception/bias on membership
	Societal influences	Gender		Influence of gender perception/bias on membership
		Personal distinctiveness		Room for authenticity, different than other makers? Can be different than others in making?
	Maker	Personal autonomy		Value in authenticity, encourages authenticity
		Personal distinctiveness		Room for authenticity, different than other engineers? Can be different than others in engineering?
Authenticity	Engineer	Personal autonomy		Value in authenticity, encourages authenticity