33rd Annual Conference of the Australasian Association for Engineering Education (AAEE 2022)
4 - 7 December 2022 – Sydney, NSW

Exploring students' perceptions of engineering design through their professional identity development and creativity

Callum Kimpton, Terence Ewe, Kathy Petkoff and Nicoleta Maynard
Monash University, Melbourne, Australia
Corresponding Author Email: nicoleta.maynard@monash.edu

ABSTRACT

CONTEXT

The role of an engineer today is multi-faceted and innovative with engineers of all disciplines working at the forefront of sustainable development in order to secure the prosperity of our society into the future. Such challenges have necessitated the need for engineers to be equipped with a range of skills that go beyond technical competencies. These adaptations of the engineering profession in the face of complex global challenges have precipitated the concept of what is known as humanitarian engineering. This research paper focuses on a first-year Engineering Design core unit in which students develop design thinking, professional skills and personal engineering vision through participating in an Engineers Without Borders humanitarian project.

PURPOSE OR GOAL

This research project aims to explore the impact of a humanitarian oriented open-ended engineering design project on the development of students' engineering identity and perceived creative opportunities. The problem statement for this research project is: **How can humanitarian oriented open-ended engineering design projects impact the development of students' engineering identity and creativity in first year students?** The two objectives that have arisen for this research project are:

1. To investigate the role of open-ended humanitarian problem-based learning on engineering students' professional identity development
2. To investigate factors that are enablers or barriers to students' perception of creative opportunities

APPROACH OR METHODOLOGY/METHODS

A qualitative research methodology was selected as the aims of this research are tightly linked with student experiences and perceptions. We employed social epistemology based on a constructivist approach as a transformative power for social change in which teachers and students are co-participants in the constructing and reconstructing of social realities. Students' qualitative responses and reflections have been thematically coded and analysed.

ANTICIPATED OUTCOMES

In this paper, we will only present the early project findings related to the impact of a humanitarian oriented open-ended design project on student creative experiences and the development of their professional identity.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Through this research investigation, the research team is aiming to provide recommendations related to best educational practices on embedding humanitarian engineering projects in engineering education.

KEYWORDS

Humanitarian engineering, engineering identity, creativity

1. Introduction

The role of an engineer today is multi-faceted and innovative, with engineers of all disciplines working at the forefront of sustainable development in order to secure the prosperity of our society into the future. Such challenges have necessitated the need for engineers to be equipped with a range of skills that go beyond technical competencies. These adaptations of the engineering profession in the face of complex global challenges have precipitated the concept of what is known as humanitarian engineering, which refers to the compassionate application of science to better the lives of those who are marginalised through the directed use of natural resources (Mitcham & Munoz, 2010).

Consequently, it has become necessary to embed the concept of humanitarian engineering in tertiary engineering courses in order to adequately equip the next generation of engineers for their careers. Engineers Without Borders (EWB) is an organisation with an overarching vision of producing and supporting technology that benefits all with a mission to "redefine the purpose and impact of engineering practice as a critical enabler of sustainable development" (Engineers Without Borders Australia, 2022). This has seen EWB become one of the global leaders in pioneering the concept of humanitarian engineering with educational projects running across primary, secondary and tertiary institutions, training programs, community projects and technological development (Engineers Without Borders Australia, 2022).

This research focuses on a first-year Engineering Design unit at Monash University, in which students learn about the engineering design process through participating in the EWB Challenge with support from the teaching staff. The EWB Challenge aims to build up the skills of first-year engineering students in the areas of professional practice, design thinking, ethics, Indigenous culture and sustainable development by integrating real-world issues regarding humanitarian engineering into the curriculum (Engineers Without Borders, 2022). Similar first-year open-ended design projects have been studied for years yielding powerful results that have in turn aided in the delivery of such units as well as student learning and performance.

Large areas of interest have included the development of students' engineering identity and analysis of student creativity through similar problem-based learning projects. It has been found that the development of an engineering identity is largely due to engagement with professional activities, social network development and sense-making (Ibarra, 2004), as well as technical skills, knowledge and experience (Eliot & Turns, 2011). Furthermore, it was postulated that leaders in engineering may only accept leadership positions when engineering identity is combined with professionally relevant conceptions of leadership (Rottmann et al., 2014).

Similarly, creativity has become a key topic of research in the field of engineering education, with much of the research focusing on first-year students enrolled in an open-ended design project (Daly et al., 2014) (Tolbert & Daly, 2013) (Starkey et al., 2016). These have become widespread in engineering pedagogy globally with the view that they beget more creative opportunities due to students engaging with real-world stakeholders and problems (Stouffer & Russell, 2004). Consequently, much research has focused on barriers to creative opportunities that include family, peers, community and educational environments (Runco & Pritzker, n.d.), with further work studying the efficacy of teaching methods and other factors on key creative cognitive characteristics (Daly et al., 2014) (Treffinger et al., 2002).

This research aims to explore students' perceptions of engineering design through their professional identity development and creativity. This is firstly motivated by the lack of studies focusing on the impact of a humanitarian engineering context on the development of engineering identity in an open-ended design project. Secondly, a need for a formal exploration of barriers and enabling factors to students' perceived creative opportunities that uses the creative cognitive characteristics framework

outlined in Treffinger et al. (2002) in a humanitarian engineering-oriented, open-ended design project.

2. Research objectives

This research project aims to explore the impact of a humanitarian oriented open-ended engineering design project on the development of students' engineering identity and perceived creative opportunities.

The research question "*How can humanitarian oriented open-ended engineering design projects impact the development of students' engineering identity and creativity in first-year students*?" stems from three key gaps highlighted in the current body of research. While there have been many papers that have investigated factors that make up the development of professional identity (Eliot & Turns, 2011), there is a lack of research exploring the relationship between open-ended humanitarian problem-based learning and engineering students' professional identity development. Secondly, studies have delved into the factors that impact the perception of creative opportunities in first-year engineering students (Tolbert & Daly, 2013) without directly assessing the specific impact of having a humanitarian engineering context concerning the design project. Finally, there is a limited amount of research that utilises key creative cognitive characteristics outlined by Treffinger et al. (2002) as an overarching structure for the analysis of barriers and enablers to perceived creative opportunities in humanitarian engineering open-ended design projects. Therefore, the two objectives that have arisen for this research project are:

1. To investigate the role of open-ended humanitarian problem-based learning on engineering students' professional identity development

2. To investigate factors that are enablers or barriers to students' perception of creative opportunities

3. Literature review and motivation

Ever since the introduction of first-year engineering design challenges by EWB Australia around Australian universities in 2007, there has been an ever-increasing number of students gaining exposure to humanitarian engineering discipline and problem-based learning (Cutler et al., 2010). Browne et al. (2010) show that problem-based activities and active learning approaches result in improved educational outcomes for all first-year students. It is different to traditional units, as students are exposed to practical real-life engineering projects, promoting the development of their creativity, professional identity and professional engineering skills.

Eliot & Turns (2011) suggest that *professional identity* can be described as the identification with the skills and responsibilities associated with a professional role. The study of engineering students' professional identity development is important as it plays an essential role in engagement, retention, and adaptation to the workplace (Ibarra & Barbulescu, 2010).

From past studies, there have been different perspectives regarding the factors that make up the development of professional identity. Ibarra (2004, as cited in Eliot & Turns, 2011) proposes the three basic processes of engagement with professional activities, social network development and sense-making as the core components of professional identity development. While there is no single agreed definition of sense-making (Brown et al., 2014), Weick et al. (2005) suggest that sense-making can be described as reflections and interpretations of past events to rationalise situations, which is crucial to the development of professional identity. Similarly, Eliot and Turns (2011) emphasise the importance of sense-making as it helps students relate their internal evaluations to external expectations in order to build their professional identity. While project-based learning offers students opportunities to interact with professional activities directly and build social networks with

peers and staff, internal sense-making activities are more limited. Thus, a good area of exploration could be the implementation of internal frame sense-making activities, such as self-reflections about their own goals and values. Eliot and Turns also highlight technical skills, knowledge and experience as key contributors to professional identity development. This is supported by Pierrakos et al. (2009), who state that participation in meaningful engineering experiences and interaction with role models, such as engineering faculty staff, are positive influences on students' professional identities. Therefore, it is important to explore students' perceptions of engineering design through their professional identity development, specifically through a problem-based design unit.

Additionally, Rottmann et al. (2014) propose a compound model of engineering leadership, where both engineering identity and professional-recognised forms of influence are required in order for engineers to accept their role as a leader. The three distinct orientations of development are classified as technical mastery, collaborative optimisation and organisational innovation (Rottmann et al., 2014). These three aspects work in conjunction for engineers to become influential leaders that benefit organisations and society. This project focuses on the relationship between problem-based learning and engineering identity rather than the key contributors to professional identity. Therefore, the study will incorporate existing theories outlined above and investigate the relationship between those factors and an open-ended humanitarian problem-based learning opportunity.

Perceived creative opportunities in open-ended engineering design projects refer to students' ability to pursue opportunities to be creative (Tolbert & Daly, 2013). This concept encompasses general definitions of creativity in engineering design projects which all place a specific focus on the ability to produce novel solutions whilst being constrained by functional requirements, which has been referred to as functional creativity (Cropley & Cropley, 2005). Furthermore, creative opportunities that are perceived by students are predicated on various enabling factors as well as barriers that must be identified and analysed in order to gain a better understanding of how creative opportunities can be fostered in the future. Many of these barriers to creative opportunities have been previously identified as stemming from family, peers, community and educational environments (Runco & Pritzker, n.d.). Conversely, it has been found that enabling factors to students' creative opportunities are more centred around their design process, with students previously having highlighted creative opportunities related to design functions, decisions, alternatives, improvements and constructing project timelines (Tolbert & Daly, 2013). Despite the body of research that exists with regard to such enabling factors and barriers to students' perceived creative opportunities in engineering design projects, there is a distinct lack of research on the impact of a humanitarian context on these factors. Therefore it is in part this research gap that has motivated this proposed research.

Open-ended design-oriented engineering projects have been commonplace in engineering pedagogy for some time now and are often characterised by their complexity and ill-defined nature without a singular process model (Swenson et al., 2021). This is done with a view to elicit creative opportunities and often involve students working in groups to address real-world stakeholders and engineering problems (Stouffer & Russell, 2004). Furthermore, there is a large amount of research that aims to quantitatively assess students' creativity in terms of key creative cognitive characteristics (Treffinger et al., 2002). Separating these creative cognitive characteristics defined by Treffinger et al. (2002) for thematic analysis has the potential to yield powerful results as it demystifies the somewhat abstract concept of creativity and makes it more practical. Daly et al. (2014) show just how influential such an analysis can be when combining teaching materials as well as self-reported student perception data to better understand the impact of open-ended engineering design projects on students' creative cognitive characteristics (Daly et al., 2014). However, such a formal evaluation of factors affecting creative opportunities and their link with overarching creative cognitive characteristics is rare in the field of engineering education, thus further motivating this piece of research which aims to combine factors that are barriers and enablers to students' perceived creative opportunities under the framework of key creative cognitive characteristics.

The engineering discipline has long been thought of as a largely technical field, with both educators and students reporting little opportunity for creativity (Kazerounian & Foley, 2007). This phenomenon has led to a large amount of research centred around teaching practices aimed at developing student design creativity and in doing so developing metrics for the quantitative assessment of student design creativity. Prominent examples of this include the Creative Engineering Design Assessment (CEDA) (Charyton & Merrill, 2009), which has been widely used and purports to measure originality and usefulness as well as both convergent and divergent thinking (Charyton, 2014). As such, the CEDA can be seen to be an incredibly powerful tool in longitudinal studies of student design creativity that can directly lead to positive changes in the delivery of engineering education. However, due to the aims, timeframe and methodology of this research project, the CEDA has not been deemed suitable for this project. A qualitative research methodology, discussed in the next section, has been employed to facilitate a richer understanding of the specific creative cognitive characteristics that the unit is enabling or blocking as well as the specific factors that contribute to this.

4. Methodology and Methods

A qualitative research methodology was selected as the aims of this research are tightly linked with student experiences and perceptions. We employed social epistemology based on a constructivist approach, described by Taylor (1996) as a transformative power for social change in which teachers and students are co-participants in the constructing and reconstructing of social realities. Understandings from this research are co-constructed by the researchers and the study participants (Hatch, 2002). It is used to describe and understand the shared phenomenon as experienced by a group of people. An approach that seeks to answer the following question: ‘What is the meaning, structure and essence of the lived experience of this phenomenon for this person or group of people’ (Patton, 2001). In this instance, the phenomenon that is intended to be explored is that of a humanitarian oriented open-ended design project with the development of students' professional identity and their experiences of creative opportunities within the project making up the data to be collected. Furthermore, this research can be deemed to follow a case study methodology which is described as a detailed examination of a distinct phenomenon (Case & Light, 2011). This is highly relevant to this research as the data for this research will comprise solely of those students undertaking Engineering Design at Monash University.

Given that a qualitative research methodology was selected, it was important to determine the method, as well as the sampling strategy and sample size required to ensure that the project produces a meaningful outcome that is representative of the given population.

As it is difficult to explore perceived creative opportunities indirectly, we have decided to utilise semi-structured informal interviews that will be thematically coded. For investigating the relationship between open-ended humanitarian problem-based learning on engineering students' professional identity development, a combination of surveys, participant observations and semi-structured informal interviews was determined to be most suitable. This allows for the triangulation of data collected from each method to enhance the depth of findings and overcome biases from using a single method (Noble & Heale, 2019). Triangulation can also allow for the convergence of datasets to support the results of the study. However, divergence can also be common in qualitative research, where findings do not support each other. This does not refute findings but actually opens up areas for further work to better understand the topic (Varpio et al., 2016).

Baker & Edwards (2012) highlight the issue of "combining sampling, data collection, and data analysis, rather than treating them as separate stages in a linear process" when researching until saturation, as it means that researchers cannot specify the number of respondents necessary at the start of a study. Dworkin (2012) recommends a minimum sample size of 25–30 participants to reach saturation when using in-depth interviews, which is supported by Adler and Adler (2012, as cited in

Baker & Edwards, 2012), who suggest a sample between 12 and 60 participants. Therefore, this project will aim to recruit approximately 30 participants for each objective. Monash University Human Ethics approval has been obtained (no. 2022-32698-76602). A research advert had been posted on the online university forums. Interested students will have the opportunity to read about the project and its aims, fill out a consent form, and will be filtered out through a selection process where the willingness and articulation of students are assessed. This should allow for a large variety of responses to be collected while achieving saturation. Additionally, there will be an emphasis on gender and background diversity amongst the participants for the engineering identity study, as their culture and upbringing will have a significant effect on their identity development. This can be achieved through filtering the potential participants to ensure a mix of students from different backgrounds are interviewed.

Unfortunately, given the timing - delay in obtaining ethics approval and students' limited availability during the break - and the timeframe for this paper, the results and findings presented in this paper have been collected via the following means: the open-ended questions focused on students' perceived creativity, originally prepared for the interviews, were asked via an online survey. All barriers and enablers to students' perceived creative opportunities identified in the survey answers were thematically coded under the four creative cognitive characteristics proposed by Daly et al. (2014). This facilitated a richer understanding of the specific creative cognitive characteristics that the unit is enabling or blocking as well as the specific factors that contribute to this. The data related to the development of professional identity was collected based on the students' end of semester written reflections. While this paper will only present findings based on the limited data collected, the authors' intention is to follow their original research methods plan, collecting and analysing data from participant observations and semi-structured interviews during the second part of this year.

5. Findings

5.1 Perceived creative opportunities

A deductive thematic coding approach was used and modelled on that which is exhibited in the work of Daly et al. (2014) where four main cognitive creative themes are identified with relevant sub-themes derived from Treffinger et al. (2002). All students enrolled in Engineering Design were invited to complete a written survey for the unit and 27 responses were collected with the sub-theme results provided in Figure 1 below.

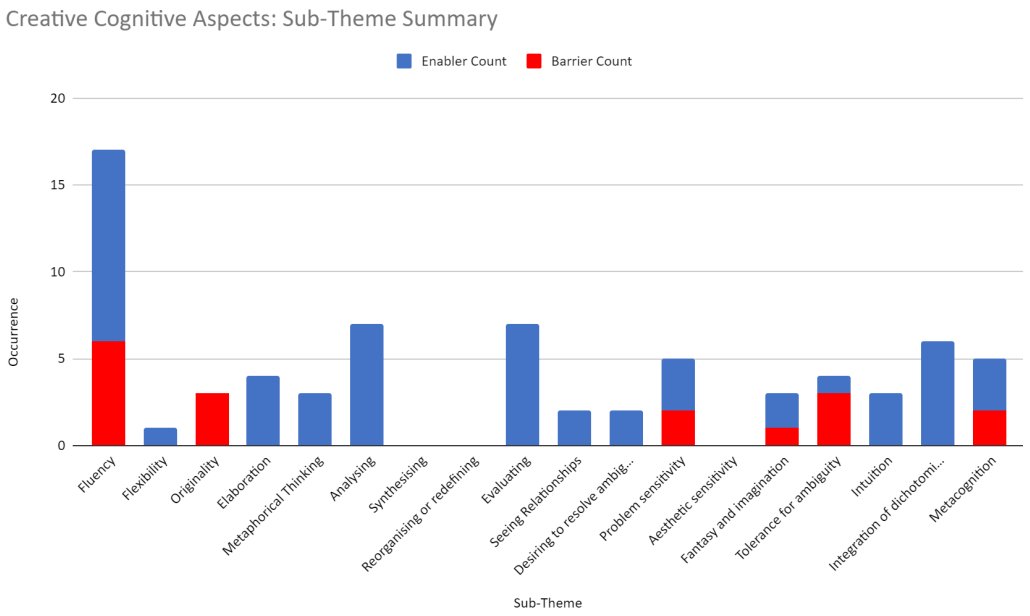

Figure 1: Summary of barrier and enabling factor counts

Table 1 below summarises some of the keywords identified in student responses within each theme.

Table 1: Summary of themes and related keywords

Theme	Keywords
Generating Ideas	Generating Ideas, Brainstorming, Generating, Collaboration, Stakeholder report, Project meetings, Workshops, Time
Digging Deeper into Ideas	Reflection, Decision, Criteria, Feedback, Critiquing, Checking, Debate, Questioning, Interrogating, Project meetings, Design evaluation report, Understanding, Research, Contextualising
Openness and Courage to Explore Ideas	Explore, Consideration, pros and cons, Project meetings, Open-ended, Support, Time, Discussion, Collaboration, Insight
Listening to One's Inner Voice	Designing, Needs, Brainstorming

It was found that Divergent thinking in general elicited the most responses with student responses showing that it was associated with both the most enabling factors and barriers when compared to other themes. Convergent thinking was associated with a very high count of enabling factors whilst students provided no evidence of barriers to digging deeper into ideas. This theme is therefore associated with the largest disparity between enabling factors and barriers to the students' creative opportunities. It was found that whilst the theme of openness and courage to explore new ideas was associated with a high count for enabling factors and a relatively low count for barriers, these were very unevenly distributed throughout the sub-themes. Tolerance for ambiguity for instance exhibited

three barriers from students whilst only being associated with one enabling factor. Conversely integration of dichotomies or opposites was not associated with any barriers to creative opportunities and six enabling factors were identified. The theme of listening to one's inner voice was widely misunderstood by students and as such was subject to very few responses.

5.2 Professional Identity Development

At the end of the semester, the students were asked to write a Professional Identity Reflection, reflecting on two main experiences: the attendance to a panel of senior and recent graduate engineers, sharing their professional experience (part 1) and the lessons learnt while working as a team throughout the semester (part 2). Part 1 required the students to reflect on one particular idea from the event that impacted their view on the engineering profession and their own development as engineers. Part 2 required them to identify and analyse a particular lesson learnt in relation to teamwork, goal setting and achievement. A reflexive and inductive thematic coding approach was used to analyse the students' professional identity reflections, as outlined by Braun & Clarke (2020). Codes are generated based on the qualitative data, and later developed into themes. Table 2 summarises the six themes that emerged from the aforementioned thematic coding approach on the students' Professional Identity Reflections. All students enrolled in Engineering Design were required to submit this reflection at the end of the semester, with 20/609 submissions analysed for this study. Reflections were chosen with the aim of introducing gender and background diversity amongst the data, as their culture and upbringing are likely to have a significant effect on their identity development.

Table 2: Summary of themes and keywords

Themes	Keywords
Development and awareness of teamwork skills	Teamwork, communication, collaboration, team, sharing ideas, collective, contribute, equal opportunity, team, cooperation
Organisation and time management	Planning, stay on task, organised, focus, procrastination, deadlines
Perseverance and resilience	Continuous, barriers, sticking to plans, hard work, determination, revisit, constant, motivation, long, complex, stress
Balance between technical and soft skills	Balance, soft skills, equal ability, technical knowledge, hard skills
Engineering is a multifaceted profession	Holistic, diverse, interdisciplinary, broad, integrate, variety, more than maths and science
Impacts of engineers on society	Impacts, environment, social, economic, stakeholders, clients, community, influence, humanitarian, issues

Table 3: Frequency of keyword themes and examples in Professional Identity Reflections

Themes	Occurrence	Examples
Development and awareness of teamwork skills	19	*"I realised that relationships in cooperative problems are subject to change and constant communication must be maintained to ensure these changing ideas and perceptions of tasks are understood and talked through by the whole team." - Student B2*
Organisation and time management	11	*"The goal I set for myself was to improve my ability to keep on track in the project by working consistently and efficiently. I do not feel that this goal was achieved, as the tendency to fall back into old habits of procrastination and the stress of other Unit deadlines interfered." - Student B11*
Perseverance and resilience	9	*"The experience contributed to my professional development as an engineer as I am aware of the fact that unexpected barriers, the ones mentioned above, are inevitable within engineering and it is my job as an engineer to tackle and resolve these as an individual and within the context of a team as well." - Student B9*
Balance between technical and soft skills	8	*"I believe this impacted me more than other moments since in my future profession of going into aerospace, from what I have seen it is heavily involved in teamwork and collaboration, but I did not think of that to be as important to the technical side of the job." - Student B14*
Engineering is a multifaceted profession	13	*"I now perceive engineering as a means to design elegant solutions for human problems and how we come to that conclusion in creative, positive, and socially responsible ways. I've learnt that science and maths are not the only things that engineering consists of, but rather, they are tools we can use to help us solve problems." - Student B8*
Impacts of engineers on society	11	*"Engineers have the potential to make large impacts and significantly improve the lives of many, including groups and communities that are less fortunate." - Student B17*

From the students' responses shown in Table 3, it was found that the development and awareness of teamwork skills was mentioned as the most common theme that contributed to their professional identity development. A majority of the students understood the importance and benefits of working in teams, specifically highlighting the ability to produce more holistic solutions and foster an effective work environment. The theme with the next highest count of 13 was broadening student's perspective of engineering, where students mentioned that the scope of engineering work and required skills were wider than their initial understanding. The remaining four themes elicited similar response counts, with around 10 students identifying those factors as important to their development. It was noted that a good number of students reflected on their preconceived notions of the roles and responsibilities of engineers, and highlighted how this unit changed their understanding of work that engineers are involved in.

6. Discussion

6.1 Factors related with students' perceptions of creative opportunities - a story about idea generation and digging deeper

The strong student response to the theme of generating ideas is to be expected in this unit largely due to the structured focus on this concept in the teaching delivery over the first four weeks. Keyword analysis from students within this theme support this contention as students referenced brainstorming, collaboration and stakeholder analysis with enabling factors to the sub-theme of fluency, all activities that made up unit deliverables or in class activities during the first four weeks of the unit. Furthermore, the large response to the theme of digging deeper into ideas is consistent with expectations as students were expected to produce an individual detailed design as a significant in-semester assessment. Students' responses highlighted in particular that the teaching enabled them to both analyse and evaluate in particular (both sub-themes having a count of 7 for enabling factors) with specific keywords recurring that included understanding, research and contextualising for the sub-theme of analysing as well as reflection, critiquing and questioning for the sub-theme of evaluating. For example, Student A4 emphasises the importance of reflection for them in digging deeper into ideas - *"Project meetings allowed me to dig deeper into ideas because I had someone to reflect upon the ideas with"*. The distinct lack of barriers identified within this theme of digging deeper into ideas is somewhat puzzling given the strong student response and general understanding of the theme. However, this could be a result of the relatively generous amount of time and resources dedicated to the detailed design portion of the unit when compared to other tasks that did not require as much convergent thinking. This claim is supported somewhat by the keyword analysis providing time or time constraints as a barrier to both the themes of divergent thinking and openness and courage to explore new ideas. Whilst the theme of openness and courage to explore ideas generally showed positive feedback with regard to students' perceived creative opportunities (15 enabling factors and 6 barriers) the sub-theme of tolerance for ambiguity was associated with three barriers and only one enabling factor. This barrier to allowing openness to uncertainty within a problem thereby limiting students' perceived creative opportunities is not one which has been discussed in depth within engineering education research focusing on design projects. However, (Giloi et al., 2019) does indicate that open-ended engineering design projects facilitate risk-taking in the decision-making stages for students which is in contrast to the preliminary findings of this study. For example, Student C11 highlights the general sense of frustration during the unit with respect to ambiguity within the project "*This was a bit frustrating so it would have been easier if we had been told all of the requirements prior to starting the project".* Previous studies have provided evidence for enabling factors to support creative opportunities centering around decisions, alternatives and improvements (Tolbert & Daly, 2013) which agrees with these preliminary findings provided in this study. This can be seen through keyword analysis of the sub-theme of integration of dichotomies or opposites where phrases concerning discussion, collaboration and insight are referenced. For example, Student A23 provides evidence of how considering alternative ideas through discussion with team members enables creative opportunities - "*Yes, I was able to explore new ideas due [to] my team members who offered insight into things I had not thought about"*. A large portion of students did not understand the written prompt for listening to one's inner voice and similarly due to the preliminary nature of this data collection we were unable to perform focus groups where we would have the opportunity to specifically reference more niche sub-themes that students would not think of organically. This could be a large reason why some sub-themes were barely referenced by students and something that will be improved for the data collection process of our full paper.

6.2 Factors related with students' professional identity development - a story about the importance of 'soft' skills, resilience and the engineers' role in the society

Given that this research only considered first semester engineering students, it was expected that they did not possess much experience working in engineering-related teams. This was evident through the reflection of Student B11, who stated that "*[n]ever in my life have I done something that requires such significant teamwork, and the associated loss of control was daunting*". Similarly, Student B4 also realised that "*it has been a bit of a shock to the system coming into [their] first year*

of university and having to be a part of multiple teams within respective units". Unsurprisingly, this resulted in the development and awareness of teamwork skills being highlighted as the most common theme that contributed to their professional identity development, as this unit places an emphasis on collaboration through an open-ended humanitarian engineering project. Through students' participation in the unit and the engineering panel presentations, they are starting to recognise the importance of teamwork in their future career, aligning with the unit outcome of "*describ[ing] the principles of team norms, collaboration and dynamics … and discern[ing] the practices that lead to successful teamwork in a multicultural context*".

Prior to beginning their undergraduate engineering degree, some students had a preconceived notion of what engineering work entails, with a common assumption being "*applications of maths and science*". However, through interacting with the EWB project and listening to the engineering panel presentations, students broaden their perspective and become aware that engineering is a multifaceted profession. As mentioned by some of the industry speakers, the skills and knowledge learnt through engineering degrees are transferable and "*do not have to strictly be applied to engineering*". Furthermore, students' views of engineering are widened through recognising the importance of interpersonal skills when working in engineering teams. Students realise that "*an engineer's role is much broader*' and '*not only about designing solutions but to solve a problem using teamwork, communication, and collaboration*". Similarly, students begin to understand the need to balance both technical knowledge and 'soft' skills in an engineering environment. While students have an initial perception that "*hard skills such as technical knowledge would be mostly important in the workplace*", their firsthand experience working in a team environment on an engineering project in their first semester allowed them to identify the need to "*develop interpersonal soft skills for team building*". This is reinforced by Student B11, who wishes "*to grow and ascertain the soft skills applicable to [their] career*' and '*build upon these skills of communication, teamwork, leadership and initiative*".

Aside from aforementioned teamwork skills, the two other themes that were evident in students' Professional Identity Reflections are organisation and time management, as well as perseverance and resilience. Generally, students mentioned organisation and time management as an area of improvement through their individual action plans, with Student B10 highlighting "*the tendency to fall back into old habits of procrastination*". This is to be expected as engineering projects often last longer than a typical assignment that students are more familiar with. Whilst there are submissions throughout the semester to keep students on track, it is not unreasonable that students fail to recognise the bigger picture, thus resulting in inconsistent work outputs throughout the weeks, eventually leading them to leaving "*certain tasks until the last couple of days before the due date"*. Similarly, the open-ended nature of this humanitarian engineering project resulted in students having to deal with more uncertainties compared to other engineering units. Some students enjoyed the creative nature of the engineering design process, but some others struggled to cope with uncertainty and were hesitant in making significant progress. While not every single student enjoyed working on the EWB project, students persevered through the hard work and difficulties, facing "*unexpected barriers … and resolve [them] as an individual and within the context of a team as well*'. This is also highlighted by Student B1, who stated that '*putting more effort into the work at hand, even when it is difficult, is advantageous to [them] in the long-term*". Previous studies by Hughes et al. (2021) also support the notion that engineering requires perseverance through failure, specifically highlighting "*the breadth and rigour of topics required for an engineering degree*" (p. 978) and "to persevere in the face of failure as a result of trial and error" (p. 978).
.

The final theme identified through students' Professional Identity Reflections is the recognition of impacts of engineers on society. As outlined in the earlier paragraphs, a good number of students had a preconceived notion of what engineering work entails. Many of these students failed to employ second level thinking when considering the roles and responsibilities of engineers. This is evident through Student B16's reflection, where they enjoyed "*how humanitarian considerations and community-based projects have been integrated into a course to which [they] previously perceived*

as very mathematical and objective". Similarly, Student B19 states that "*engineering can be far more humanitarian … and was surprised to learn how much of an impact engineers can have on important world issues, which is something completely foreign to [their] previous understanding of engineers*". Thus, the implementation of an open-ended humanitarian engineering project plays an important role in students' professional identity development, especially in raising "*awareness [of] the power and responsibility engineers are entrusted by society to deliver projects and solutions that have the potential to impact lives of those around them*".

7. Recommendations and Limitations

From the research perspective and scope of the project, there are some limitations as it is mainly a case study on the Engineering Design unit over a single semester. This means that trends will be specific to the unit as well as first-year Monash University students. Furthermore, it is likely that the delivery of the unit will change over the semesters through feedback from students due to it being taught for the first time in 2022. However, this study will have implications for educational pedagogy, as it allows the teaching staff to recognise successful aspects of the unit and address areas of improvement for future semesters.

Given the preliminary nature of this study due to the limited data collection methods used, there are gaps in the research method that need to be addressed in our full study. The use of broad written responses and reflections resulted in a lack of detailed first-person perspectives regarding their personal experiences. For our full study, we will be employing participant observations and will be implementing in-depth, semi-structured interviews to allow for more detailed insights and follow up questions. This should result in participants being more open and comfortable to share their first-person experiences and thoughts, as well as allowing the researchers to probe into any areas that require more depth. An area of interest that was not covered in the students' reflection is the relationship between their culture and upbringing on their perceived notions of engineering and professional identity development. This could be explored in-depth in the final study.

Despite the lack of detailed data, there is some strong evidence for particular creative cognitive themes being associated with enabling factors and barriers to students' perception of creative opportunities within open-ended humanitarian-oriented design. Similarly, the prevalence of certain themes in students' Professional Identity Reflections allow us to form preliminary conclusions on the effect of humanitarian oriented open-ended engineering design projects on the development of students' engineering identity. These preliminary results give us a good indication of what to expect in the final study as well as where to improve, by addressing the gaps in the research question and specifically focusing on sub–themes that were not readily referenced by students in this study.

Some potential recommendations for future work could be collecting similar data from other universities conducting comparable units, so that results can be triangulated and compared. As both our preliminary study and consequent full study do not have a longitudinal component, it may also be beneficial for future work to focus on the longitudinal study of both professional identity development through open-ended humanitarian problem-based learning, as well as barriers and enabling factors to students perceived creative opportunities.

References

Baker, S., & Edwards, R. (2012). How many qualitative interviews is enough. National Centre for Research Methods Review Paper. Retrieved 8 April 2022, from https://eprints.ncrm.ac.uk/id/eprint/2273/4/how_many_interviews.pdf.

Browne, C., Blackhall, L., Duynhoven, A., & Smith, J. (2010). Embedding EWB Development Projects in an Engineering Program.

Braun, V., & Clarke, V. (2020). Can I use TA? Should I use TA? Should I not use TA? Comparing reflexive thematic analysis and other pattern-based qualitative analytic approaches. Counselling and Psychotherapy Research, 21(1), 37-47. doi: 10.1002/capr.12360

Case, J., & Light, G. (2011). Emerging Research Methodologies in Engineering Education Research. Journal of Engineering Education, 100(1), 186-210. https://doi.org/10.1002/j.2168-9830.2011.tb00008.x

Charyton, C. (2014). Creative Engineering Design Assessment (pp. 1-7). Springer London.

Charyton, C., & Merrill, J. (2009). Assessing General Creativity and Creative Engineering Design in First Year Engineering Students. Journal of Engineering Education, 98(2), 145-156. https://doi.org/10.1002/j.2168-9830.2009.tb01013.x
Cropley, D., & Cropley, A. (2005). Engineering creativity: a systems concept of functional creativity. In J. C. Kaufman & J. Baer (Eds.), Creativity Across Domains: Faces of the Muse (pp.169-186). London: Lawrence Erlbaum Associates.
Cutler, S., Borrego, M., & Loden, D. (2010). Evaluation of the Engineers Without Borders Challenge at Western Australia Universities.
Daly, S., Mosyjowski, E., & Seifert, C. (2014). Teaching Creativity in Engineering Courses. Journal of Engineering Education, 103(3), 417-449. https://doi.org/10.1002/jee.20048
Dworkin, S. (2012). Sample Size Policy for Qualitative Studies Using In-Depth Interviews. Archives of Sexual Behavior, 41(6), 1319-1320. https://doi.org/10.1007/s10508-012-0016-6
Eliot, M., & Turns, J. (2011). Constructing Professional Portfolios: Sense-Making and Professional Identity Development for Engineering Undergraduates. Journal of Engineering Education, 100(4), 630-654. https://doi.org/10.1002/j.2168-9830.2011.tb00030.x
Engineers Without Borders Australia. (2022). *Engineers Without Borders Australia: Creating change through humanitarian engineering. Engineers Without Borders Australia*. Retrieved 1 April 2022, from https://ewb.org.au/.
Engineers Without Borders Australia. (2022). *About EWB - Engineers Without Borders Australia*. Retrieved 3 April 2022, from https://ewb.org.au/aboutewb/.
Giloi, S., Barry, C., Burger, Y., Harrison, P., Krueger, L., Scheffer, L., & Walton, C. (2019). Undergraduate design students' experience of risk-taking in an open-ended design project. *Art, Design &Amp; Communication in Higher Education*, *18*(1), 35-50. https://doi.org/10.1386/adch.18.1.35_1
Hatch, J. (2002). Doing qualitative research in education settings. State University of New York Press.
Hughes, B., Schell, W., Tallman, B., Sybesma, T., Kwapisz, M., & Annand, E. et al. (2021). Entering the community of practice: changes in engineering students' engineering identities and perceptions of the field. European Journal of Engineering Education, 46(6), 968-986. https://doi.org/10.1080/03043797.2021.1947197
Ibarra, H., & Barbulescu, R. (2010). Identity as narrative: Prevalence, effectiveness, and consequences of narrative identity work in macro work role transitions. Academy of Management Review, 35(1), 135-154. https://doi.org/10.5465/amr.2010.45577925
Kazerounian, K., & Foley, S. (2007). Barriers to Creativity in Engineering Education: A Study of Instructors and Students Perceptions. Journal of Mechanical Design, 129(7), 761-768. https://doi.org/10.1115/1.2739569
Mitcham, C., & Munoz, D. (2010). Humanitarian Engineering. Synthesis Lectures on Engineers, Technology and Society, 5(1), 1-87. https://doi.org/10.2200/s00248ed1v01y201006ets012
Noble, H., & Heale, R. (2019). Triangulation in research, with examples. BMJ Journals. Retrieved 8 April 2022, from https://ebn.bmj.com/content/22/3/67.
Patton, M. (2001). Qualitative Research and Evaluation Methods. Organisational Research Methods, 5(3), 299-301.
Pierrakos, O., Beam, T., Constantz, J., Johri, A., & Anderson, R. (2009). On the development of a professional identity: engineering persisters vs engineering switchers. 2009 39Th IEEE Frontiers in Education Conference. https://doi.org/10.1109/fie.2009.5350571
Rottmann, C., Sacks, R., & Reeve, D. (2014). Engineering leadership: Grounding leadership theory in engineers' professional identities. Leadership, 11(3), 351-373. https://doi.org/10.1177/1742715014543581
Runco, M., & Pritzker, S. Encyclopedia of Creativity (p. 165). Academic Press.
Starkey, E., Toh, C., & Miller, S. (2016). Abandoning creativity: The evolution of creative ideas in engineering design course projects. Design Studies, 47, 47-72. https://doi.org/10.1016/j.destud.2016.08.003
Stouffer, B., & Russell, J. (2004). Making the Strange Familiar: Creativity and The Future of Engineering Education. 2004 Annual Conference Proceedings, 9.883.1 - 9.883.13. https://doi.org/10.18260/1-2--13891
Swenson, J., Beranger, K., & Johnson, A. (2021). How Students Take Up Open-ended, Real World Problems. 2021 IEEE Frontiers in Education Conference (FIE), 1-5. https://doi.org/10.1109/fie49875.2021.9637362
Taylor, P. (1996). Mythmaking and mythbreaking in the mathematics classroom. Educational Studies in Mathematics, 31(1-2), 151-173. https://doi.org/10.1007/bf00143930
Tolbert, D., & Daly, S. (2013). First-Year Engineering Student Perceptions of Creative Opportunities in Design. International Journal of Engineering Education, 29(4), 879-890.

https://www.researchgate.net/publication/287451126_First-Year_Engineering_Student_Perceptions_of_Creative_Opportunities_in_Design
Treffinger, D., Young, G., Shelby, E., & Shepardson, C. (2002). Assessing creativity: A guide for educators. Storrs, CT: National Research Center of the Gifted and Talented.
Varpio, L., Ajjawi, R., Monrouxe, L., O'Brien, B., & Rees, C. (2016). Shedding the cobra effect: problematising thematic emergence, triangulation, saturation and member checking. Medical Education, 51(1), 40-50. https://doi.org/10.1111/medu.13124
Weick, K., Sutcliffe, K., & Obstfeld, D. (2005). Organizing and the Process of Sensemaking. Organization Science, 16(4), 409-421. https://doi.org/10.1287/orsc.1050.0133

Copyright statement