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Exploring Engineering Identity Development Through an Arts-based Approach (EESD2025)

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Abstract

This educational research paper explores engineering identity development among international students in a foundation program at a UK university. Engineering identity is a phenomenon that describes how one sees themselves as an engineer, and it has important social and academic implications for students, such as persistence and sense of belonging. The study context is a yearlong engineering module (class) that is taken by international students as part of a foundation program, in which they complete one year of study before progressing into their undergraduate degree. The module thus provides an opportunity to introduce students to not only fundamental physics and design concepts, but also what it means to be an engineer through a macroethical lens, in which engineering has a responsibility to societal and environmental issues like sustainability. A framework for developing the module was the Inner Development Goals, a set of skills and qualities needed to address the UN Sustainable Development Goals (SDG). To understand if/how students see themselves as engineers and whether that sense of identity changed throughout the year of study, students completed the 'draw an engineer' test on the first and last days of class. This activity is a written reflection on what engineering is, what engineers do, and what an engineer looks like at work. Analysis of the open-ended responses and student drawings of engineers is presented to provide insight into students' preconceptions of engineering, the extent to which students see themselves as engineers, and the extent to which sustainability is integrated with their understanding of engineering. Given the role of engineering identity in shaping students' academic experience and persistence, this exploratory research contributes an empirical understanding of identity development of international students who are navigating study in a new country and their first formal exposure to engineering through a macroethical lens.

1 Introduction

1.1 *Engineering Identity*

Engineering identity development is the complex and layered phenomenon of how individuals who study or practice engineering see themselves as engineers (Patrick & Borrego, 2016). Research on engineering identity has grown in recent years as a framing for exploring ongoing challenges, such as persistence and inclusion (Huff & Ross, 2023). There are multiple perspectives for understanding engineering identity, as explained by Huff and Ross (2023). The personal perspective describes how students and practitioners build

their identity to answer, “who am I as an engineer?”. The social perspective addresses how social contexts shape people and their definition of self as an engineer. Sociocultural takes a broader view of how the sociocultural context constructs the identity of groups. Engineering identity and the culture of engineering are tightly coupled as who becomes an engineer, how they develop a sense of belonging, and whether they internalize it as part of their sense of self is shaped by the norms, values, and practices of engineering and the implicit and explicit understanding of who is included in, and excluded from, this group. A review on engineering identity has shown that engineering is associated with problem solving and knowledge of maths and science (Morelock, 2017) and that engineering has a technical and masculine culture (Faulkner, 2007).

Given the different perspectives for understanding what an engineer is and how someone becomes an engineer, there are cultural and contextual factors that help explain engineering identity development in the present study, which are synthesized briefly in the following sections.

1.2 International Student Experience

The study of engineering identity also involves the consideration and interaction with students’ other identities, such as gender, race, and ethnicity (Rodriguez *et al.*, 2019). In the present study, all the students are from outside of the UK, as the program was designed for international students. International students represent one quarter of the university population in the UK, making it one of the most popular destinations for study (Bolton, Lewis, & Gower, 2023). Students come from a range of backgrounds, all of which influence their personal identity that intersects with their academic and professional identity as engineering students.

1.3 Macroethics

In light of the traditionally technical focus of engineering education, there has been momentum in the past few decades to expand the skills relevant to engineering. Driven by accreditation, policy, and industry, the learning outcomes of engineering students have expanded to include ethics, diversity, environmental impact, and responsibility (e.g., ABET, Washington Accord, and AHEP). These outcomes relate to macroethics, the broad responsibilities of engineers to society and the environment (Herkert, 2005). Sustainability is one such macroethical responsibility because it integrates addressing the needs of the natural world while also meeting the needs of current and future generations. This macroethical view of engineering shaped the design of the module that was the focus of the present study.

2 Module Design

2.1 Study Context

The present study was situated in a yearlong introduction to engineering module for students in a foundation program. The program provides one year of study prior to starting the undergraduate degree; if students meet the progression requirements for their chosen bachelor’s course, they are guaranteed admission. Students who take the engineering module are also required to take maths, science and society, and English with all the STEM students. The program offered engineering for the first time in 2023/24; it was previously combined with computer science and taught by an academic in informatics. In the first cohort, there were

33 students, 52% of whom were female. Additional information on the module and its development has been published (Polmear, 2024).

Since the module was being offered for the first time, it was an opportunity for a new vision of an introduction to engineering. Beyond the specifications of covering physics in the first term and engineering design in the second term, there was flexibility in designing the course content. In alignment with the macroethical view of engineering, the Inner Development Goals (IDG: Inner Development Goals, 2021) were used as a framework. The IDG are a set of skills and qualities needed to address the UN Sustainable Development Goals (SDG). This framework was selected because it integrates engineering identity and macroethics through the notion that what it means to be an engineer includes the skills and attitudes needed to address complex, sociotechnical-environmental issues. There are five goals (included in Table 1): being (relationship to self), thinking (cognitive skills), relating (caring for others and the world), collaborating (social skills), and acting (driving change). To identify evidence of these goals in students' understanding of engineering, the framework was used to analyze the Draw an Engineer Test data, as detailed in Section 3.2

3 Research Methods

3.1 Data Collection

Data for this study were extracted from an activity that students completed during the first seminar (in September 2023, the “pre-test”) and last seminar (in April 2024, “the post-test”). The activity was based on the Draw an Engineer Test (Knight & Cunningham, 2004), which was modified from the Draw a Scientist Test (Chambers, 1983). The Draw a Scientist Test was designed to understand the age at which young students started representing stereotypical ideas of scientists. The research showed that in primary school, children start portraying standard images of scientists, such as eyeglasses, facial hair, and lab coats. The Draw an Engineer Test was similarly developed to understand perceptions of engineers and has been used with primary through pre-university students (Knight & Cunningham, 2004). The test leveraged the power of images through drawings since people use images to make sense of their experiences and make the abstract concrete (Knight & Cunningham, 2004). The questions included:

- In your own words, what is engineering?
- What does an engineer do?
- Draw a picture of an engineer at work.
- Do you know any engineers?
- If so, who are they?

Since the module was most students' first formal exposure to engineering, it provided insight into their baseline conceptions of engineering. The post-test was used to understand if there were any shifts in their understanding of engineering, with a particular focus on evidence of the Inner Development Goals. There were 30 submissions for the pre-test and 22 for the post-test.

3.2 Data Analysis

The Inner Development Goals were used as the analytical framework for the open-ended responses and pictures in the Draw an Engineer Test activity. In the first round of coding, the components for each goal (shown in Table 1) were used as deductive codes (Bingham & Witkowsky, 2021). The second round of coding involved revisiting the data under each code to identify themes, which are presented in the findings.

Table 1: Inner Development Goals as the analytical framework

Goal	Components	Example from Data
Being: relationship to self	Inner compass Integrity and authenticity Openness and learning mindset Self-awareness Presence	
Thinking: cognitive skills	Critical thinking Complexity awareness Perspective skills Sense making Long term orientation and visioning	“[Engineering is] using technology and critical thinking and problem solving”
Relating: care for others and the world	Appreciation Connectedness Humility Empathy and compassion	“Engineering is applying physics concepts in reality to help people and communities develop for the best”
Collaborating: social skills	Communication skills Co-creation skills Inclusive mindset and intercultural competence Trust Mobilisation skills	“Engineers work collaboratively and come up with ideas to solve our issues”
Acting: enabling change	Courage Creativity Optimism Perseverance	“Engineering revolves around solving problems in a creative way”

3.3 Positionality

As the first author, my identity and background shaped my perspectives and approaches as both an educator and researcher. I designed and taught the module, and I viewed it as an opportunity to integrate a holistic understanding of engineering, which was largely influenced by my research on engineering ethics education and workforce development. These two strands of research brought into focus the importance of integrating ethical and societal impacts of engineering in the curriculum and teaching them alongside technical content to highlight their interconnection and relevance to engineering. My own macroethical view of engineering thus largely influenced my pedagogical approach, while I also worked within the constraints of the learning outcomes that had already been established.

As the second author, I was involved in the module as the graduate teaching assistant. The role included teaching weekly seminar sessions and facilitating data collection for this study.

4 Findings and Discussion

4.1 Engineers are problem solvers

The most frequent code related to the “thinking” goal with the Inner Development Goals. As an example, critical and analytical thinking were commonly cited in defining engineering and describing what an engineer does. These skills, along with the application of math and science, were often used to describe how engineers are problem solvers. In the pre-survey, 20 of the 30 students described engineering as solving problems or finding solutions, suggesting the prevalence of this idea in their preconceptions of engineering. In comparison, in their study using the Draw an Engineer Test with students in grades 3-12 in the United States (ages 8 to 18), Knight and Cunningham (2004) found “builds”, “fixes”, and “creates” were most commonly associated with what an engineer does.

4.2 Engineers help others and improve the world

Data within both the “thinking” and “relating” goals reflected the societal importance of engineers and their ability to help people. As examples in the pre-test, students viewed engineering as “improving society”, “improving the quality of people’s lives”, and “making the world a better place”. Similar ideas were reflected in the post-test, such as “help humanity”, “serve humanity”, and “improve the world”. There was a similar prevalence of these codes in the pre- and post-tests, indicating that students entered their study with the idea that engineering can help people and improve the world, and the module reinforced that understanding. The responses also reflected the broad impact of engineers and the role they play in everyday life, such as “everything we use like the tools and machines or things we see around us in a result of the work of an engineer”, “it [engineering] is the basis of life”, and “[engineering is] the essence of life, everything you look at is engineered [...] without it, our roads and houses would not be build.” These responses speak to perceived importance and impact of engineers, which was more prevalent in the pre-test.

4.3 Students developed broader idea of who can be an engineer, including themselves

In looking at the codes across the pre-and post-survey, the data suggested a broader understanding of who can be an engineer, including themselves. Most of the drawing in the pre-test were stick figures with stereotypical images of engineers, such as hard hats and cranes. This finding is similar to Knight and

Cunningham's study of the frequency of images of tools, computers, and hard hats. The post-test indicated more specificity and personal relevance. For example, a student drew a stick figure and a small wind turbine with the caption "his first project". In the module, the students worked in groups to design and manufacture a small-scale wind turbine, suggesting the student started to see themselves as an engineer who completed their first project. Another student drew a figure using Fusion and then going "to a makerspace to make his prototype come to the real world". This drawing reflected the design process used in the module as students used Fusion 360, a computer-aided design software, and the engineering makerspace to create their projects. As another example, a student drew a wind tunnel and turbine for an engineer at work, which again reflected what was covered in the module through the design project and an aerodynamics lab.

Another example of changing understanding of engineering was reflected in how gender was portrayed in the drawing. As an example, one female student drew a man in a suit on the pre-test. The picture was accompanied with the explanation, "I always think of an engineer with glasses and also with a shirt and tie." On the post-test, she drew a woman engineer with the caption, "not a man wearing glasses and a tie this time." Knight and Cunningham (2004) found both male and female students were more likely to draw male engineers, and female students were more likely than male students to draw a female engineer.

5 Future Work

This exploratory study highlighted opportunities for future work related to research and practice. Based on the preliminary findings, some changes were made to the module in 2024/25. As one example, the contribution of diverse engineers was highlighted in every lecture. As part of attendance monitoring, there was a word of the day, and this was used to discuss one engineer from a historically underrepresented group who made a significant impact on engineering but might not be well known. The aim of this change was to continue broadening students' understanding of who is and who can be an engineer.

Future work will analyze and compare the second cohort of students in 2024/25. There are also opportunities for more in-depth analysis, such as looking at the representation of gender in the images and use of pronouns. Additional analysis can also consider the prevalence of specific SDGs.

6 Conclusion

This is an exploratory study of understanding engineering identity and macroethics in an introduction to engineering module within a UK foundation program. This work aims to contribute the Inner Development Goals as a novel framework for integrating engineering identity and macroethics, both in terms of designing a module and providing insight into how students see engineers and engineering. The analysis of the pre- and post-tests using the Draw an Engineer Test indicates students see engineers as problem solvers and that they help others and improve the world. There was also evidence that students developed a broader and more personalized view of engineering, which might have supported seeing themselves as engineers.

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