Student Teachers' Understanding of Connections between Engineering Practice and Technology Education

Wendy Fox-Turnbull and Paul Docherty

Technology education and engineering are closely related. In schools when students are engaged in designing and making some outcomes it may be referred to as engineering, technology or more recently as STEM depending on national curricula. Whatever its name the undertaking of technology practice in schools has many similaraties with and therefore could lead students into engineering and engineering related careers, subsequently referred to engineering careers. It is perceived as desirable that engineers have a variety of characteristics included those that are typically associated with being 'female' such as considering social and moral issues impacts and empathy; however, in the Western world female numbers are very low in engineering careers. This paper is based on the premise that it is important to understand how and why this has come about. Girls need to be encouraged into engineering careers especially those fields traditionally dominated by males such as civil, mechanical and software engineering. Before we can address this issue it is important to understand what teachers understand about the links between school based technology education and engineering. As students between the ages of 11-13 years make critical decisions related to their career choice. As teachers influence their students both overtly and subliminally in this choice it is important to explore teachers' views of engineering and technology, accordingly this paper reports on a study investigating student primary teachers' views on engineering and its links with technology education. The results indicate that just under half of the students recognised technology as a precursor to engineering or that aspects of technology relate to aspects of engineering, however the data suggests that some of the participants recognised links based on flawed understanding of either technology or engineering.

Keywords: Technology education, engineering practice, diversity, career selection

Introduction

Engineering practice is increasingly challenged and changing as our world increases in complexity. Solving complex engineering problems involves the consideration of a wide range of factors and issues. To assist catering for these complex issues engineering practice needs to change. Collaboration, creativity analytical thinking, knowledge sharing, and interdisciplinary thinking and practice must be add to 'traditional' engineering knowledge and skills (Du & Kolmos, 2009).

To assist the implementation of new thinking and practice increasing diversity of those entering the engineering profession is required. Diversity among engineers is desirable as diverse groups of people work in diverse ways. One particularly relevant reason is to do this is to improve the quality and creativity when working within increasingly complex problems. Non-diverse professions miss out on valuable contributions and new ways of approaching problems that a varied workforce brings (Schäfer, 2006). People from diverse backgrounds bring a wider range of ideas to potential solutions and give greater voice to often-marginalised populations. (Dasgupta & Stout, 2014; Hill, Corbett, & St Rose, 2010; Weber, 2012; Weber & Custer, 2005). This paper outlines an aspect of a larger study that investigated student teachers's views on engineering. it identifies student teachers' understanding of links between technology education and engineering in the hope to gain some insight into the lack of females in the profession in New Zealand.

Literature Review

Technology education engages students in the solving of authentic problems through the development of technological solutions (Ministry of Education, 2007). When involved in authentic technological practice students are more likely to become engaged and motivated (Fox-Turnbull, 2012). Inquiry-based technology practice facilitates students' engagement in collaborative learning, creative and analytical thinking and the facilitation of interdisciplinary and transdisciplinary integration of skills and knowledge from a range of disciplines (Snape & Fox-Turnbull, 2011). Williams (2011) proposes that technology and engineering are closely related but questions the position of knowledge and skills in relation to the relevant problem. He suggests that within technology studies the problem and necessary skills and knowledge are inseparable and worked with conjointly. As outlined in Table 1, Technological skills and knowledge are learned, before application to a problem, however in engineering, the context defines the skills and knowledge deployed by the engineer, who draws from a deep theoretical and practical skill set and previous experience.

Table 1. Positioning of Design and Technology and Engineering (Williams, P. J., 2011, p 98)

Schooling	K-10	11-12
Subject	Design and Technology	Engineering
Focus	General	Vocational
Process	Designerly	Analytic, Math/Sc dependent
Knowledge	Defined by the problem	Defined by the context

Increasing diversity within engineering is very important as global problems are becoming increasing complex (Cadaret, Hartung, Subich, & Weigold, 2017; Godwin, Potvin, Hazari, & Lock, 2016). Stereotypical prejudices of engineers and engineering influence those who seek careers in the field and thus ultimately lead to the lack of diversity in engineering practice (Ahmed, Basantis, & Jahan, 2019; Barnard, Hassan, Bagilhole, & Dainty, 2012; Dasgupta & Stout, 2014; Hill et al., 2010; Weber, 2012; Weber & Custer, 2005). The disparity not only contributes to income, social status and social-mobility discrepancies, it perpetuates stereotypes. Gutierrez, Paulosky, Aguinaldo, and Gerhart (2017) suggest that as more and more women enter the engineering profession they begin to shape the direction of the field. A diverse workforce facilitates identification of more opportunities; increases ways of viewing new opportunities; enables greater complexity of ideas and the recruitment of a wider range of resources. Diverse ideas and different ways of seeing the world enable a wider range of potential solutions. Varied and diverse perspectives and experiences also better facilitate the addressing of unpredictable needs of the future (Gutierrez et al., 2017).

Many influences cause young people to reject engineering as a potential career. However, research has shown that these influences tend to be psychosocial rather academic (Hill et al., 2010; Lamb et al., 2018). Lloyd, Gore, Holmes, Smith, and Fray (2018) identify three key influences on career choice in Science, Technology, Engineering and Mathematics (STEM) related careers: positive attitudes and interests, self-efficacy and persistence; appropriate soft skills and stable tendencies related to cognition. Even when selecting a career in science fields girls tend to gravitate towards humanity related professions such as medicine and health (Koppel, Cano, & Heyman, 2002). Those girls who do enter engineering tend to move into disciples within engineer that are socially and environmentally aware such as environmental and biomedical engineering. To combat this engineering courses need to deploy non-biased gender neutral pedagogies such as problem solving and collaborative and team work approaches (Gutierrez et al., 2017; Koppel et al., 2002) and include humanities and non-technical aspects to their course (Nguyen, 2000).

Teachers play a role in career selection of their students. While it is acknowledged that parents and family values have the greatest influence (Kazi & Akhlaq, 2017; Lloyd et al., 2018), teachers and educational settings are also recognised as playing a role (Kazi & Akhlaq, 2017; Krumboltz, Mitchell, & Jones, 1976). There appears to be consensus that academic achievement and perceived academic ability also influence students' career selection (Kazi & Akhlaq, 2017; Krumboltz et al., 1976; Lloyd et al., 2018). Kazi and Akhlaq (2017) state that students should not be forced or pushed into careers that they do not want to enter, however they also identify that students often make career decisions with limited knowledge of the real world, thus students are making life-changing decisions when ideas are not fully informed. It is therefore vital that those who influence students' career selection have accurate representations of these careers.

As well as directly influencing career selection; teachers also have a high level of influence on their students' self-perception, self-image and perceived capability, therefore also indirectly influence perceptions of abilities, self –esteem and efficacy and ultimately career selection. To improve the quality of their influence teachers need to hold accurate accounts of careers so that messages, explicitly and implicit are based on fact rather than stereotype. Prior research infers that children aged 11-13 years make critical decisions about their future careers (G. Jones, Taylor, & Forrester, 2011; Lamb et al., 2017; Low, Yoon, Roberts, & Rounds, 2005). A number of researchers have found that at this age children are influenced away from considering careers in engineering by their perceptions, attitudes and beliefs about the scope and components of engineering careers and their perceived abilities in maths and science (Ahmed et al., 2019; Godwin et al., 2016; Weber & Custer, 2005).

Teachers have a known influence on students' thinking and career selection can occur through a range of avenues (Kazi & Akhlaq, 2017; Krumboltz et al., 1976; Lloyd et al., 2018). Improving enrolment of women in engineering depends on the way in which the profession is presented to students while at school (Nguyen, 2000). Krumboltz et al. (1976) and Kazi and Akhlaq (2017) suggest teachers influence female students' decisions to enter (or not) engineering in numerous ways. Three critical ones (summarised in Table 2) include the design of current courses and the pedagogical approaches deployed by teaching staff, teachers' attitudes and perceptions of engineers and engineering related careers perpetuating current stereotypes and. students' beliefs and feelings about how they see themselves, their abilities and their potential.

Table 2. Teachers Influences of Female Selection on Careers in Engineering

Teachers' factors of influence	**Summary of influence**
Existing course design and pedagogy	Courses that are technological and skills-based discourage female enjoyment and enrolment in subsequent courses
Attitudes towards Engineers	Speaking about engineers and engineering to either perpetuating or dispelling stereotypes
Students' self-efficacy	Teachers comments, actions and biases influence students' sense of self and therefore their belief about potential future careers

Without a well-developed understanding of engineering and technology education teachers are in danger of either consciously or unconsciously putting students, particularly girls off considering careers in engineering thus the aim of the research is to determine the student teachers' views of engineers and engineering, and to understand the links they were able to identify key commonalities between the curriculum learning area of technology education in the New Zealand Curriculum (Ministry of Education, 2007) and the engineering profession. The research question is: What are student teachers' perceptions of the links between technology education and engineering?

Methodology and Methods

This study was framed through a constructionist epistemological stance, identified by Crotty (1998) as the understanding that individuals construct meaning through their experiences, the tools they use, the networks of people they engage with thus constructing knowledge through interactions with others within a socio-cultural environment. This is underpinned by Vygotsky's social cultural theory within which cognitive development is dependent upon an individual's responses to cultural and societal influences.

This study used a qualitative approach using individual semi-structured interviews with 19 primary teacher education students from two New Zealand universities, one from the South Island with nine participants and one from the North Island with ten participants and two of their lecturers, one from each university. Participants were in their final year of a three-year undergraduate degree or graduates undertaking a one-year graduate diploma in teaching and learning. The two staff lectured in technology education. Table 3 outlines demographic data gathered. Of the nineteen students, three were male; anecdotally this is a typical ratio of males to females in primary teacher education programmes in New Zealand. The students ranged in age from 20 -74 years. One lecturer was over 60 and the other within the 35-60 age range.

Table 3. Demographic Information

Age in Years	15-22	23-35	35-60	60+	n
Lecturers			1F	1F	2
Students	6F	2M, 6F	1M, 3F	1F	19 3M, 16F

F = female M=male

Ethical clearance sort and obtained from the leading unversity's College of Education ethics committee. Additional consent was obtained from the Dean of the Faculty of Education in the second university before data gathering began. Participants volunteered and were able to withdraw from the study at any time. Pseudonyms were used to assist with anonimity. In the second university the reseacher was a lecturer of all of the particpants. For their protection interviews were not undertaken until after course grades were submitted.

Semi-structured interviews were used to enable the participants' views of engineering, the characteristics of children who might become engineers and the links perceived between technology and engineering to be explored through narrative and reflection (Mason, 2018). All participants were voluntary and gave informed consent. Interviews took between 30-55 minutes. To increase reliability and avoid participant bias interviewees were initially told the study was to determine their views about a range of careers, rather than specifically engineering. To this end, interviews included initial questions about a range of occupations. Again, to improve the reliability of the data from participants from two universities were used.

All interviews were transcribed using transcription services and were subsequently checked for accuracy by the researchers. The software tool NVivo was used to assist data organisation and analysis facititating the identifcation of themes and subthemes.An interpretative approach facilitated the analysis of the transcribed interviews, with meaning interpretated from the data (Mason, 2018). The data set was analysed, coded, and recoded using a thematic approach. Researcher background was also a consideration as one was a teacher educator and the other an engineer. Cross checking between researchers ensured researcher bias was kept to a minimum (Mason, 2018). Both Open and Analytic coding were used. Open coding allowed the researcher to attach simple labels to data to identify categories and define data properties. Analytic coding facilitative a deeper interpretive coding giving a more explanatory and analytic meaning to the data (Cohen, Manion, & Morrison, 2001).

Findings and Discussion

The investigation into students' teachers understanding of the links between technology and engineering identified three themes: 'Precurser to Engineering', 'Opportunities for Integration' and 'Technology as Tools'. No students made links to technology when asked about engineering. However links were made when specifically probed about possible links. Before reporting this, it is important to note that all participants had undertaken some study in teaching technology education as a part of their ITE programme. This typically varies between universities; in both the institutions used in this study, the students had completed 8-8.5 credits, which is the equivalent of 80-85 hours of study.

Particpants' views of engineers and engineering were very similar to sterotypical views of engineering identifed in the literature (Godwin et al., 2016). This approach is exemplified by the following quote.

> Engineering, I automatically just think of people that build the roads and bridges and buildings and how everything is made, how structures are made safe. Yeah. That's probably not the most technical and then yeah, but that's just what I think of straightaway (Polly).

Of the 20 participants 13 participants stated engineering was practical; with most of these mentioning building and or construction although there was some confusion in defining "building" as exemplified by Joan "I'm not 100% sure. I know the building and I think mechanics [might] come under it. I'm not 100% sure on that". Some particpants identifed a range of tasks related to engineering.

> Engineering is about name- it's like building things, maintaining things, and this society like big bridges or it could be electrical engineering, so, like that dollar systems and all of that. Just maintaining that, making a bit of creative and stuff (Lynn).

Additionally number of participants thought that engineers were involved in fixing or repairing machines and cars, some thought this was all engineers did and others recognised repair as a part of engineering.

> The structural engineers, they fix anything that need to deal with dams or bridges, or make… so the whole making aspect of it too, they're making, fixing and repairing, maintaining. The technical tasks ....you need to do make it move and how do we fix it, how do we do that debugging, just where the digital technology is coming.......... So the technical tasks of an automotive [engineer] might be looking at the engines of cars, looking at fixing the outer part of the car, looking at changing tyres, looking at axles or typical little nit-picky parts of car maintenance, how cars run (Amy).

It is clear from the quotes above that students were able to identify that engineering was a practical profession, as is technology education (de Vries, 2017), however none of the particpants volunteered the connection with technology education until probed, suggesting that the link was not obvious to them initially.

Design was another apsect of engineering that was recognised by a number of particpants. Tania stated "They design, like they create bridges and designs structures". One aspect of design that was mentioned frequently was the need for engineers to be creative. George stated that engineers needed to "come up [with] a backup solution", and Cody identifed as a hurdle for engineers "the inability to think past to only look at a solution from one side". Isabel who had a family member in engineering, also identifed design as a component of engineering.

> because my brother is an engineer. He used to work with machines but now he's designing windows. So it's very broad. Sometimes I'm so what's with designing windows? Windows are square. You don't know. So it's very broad. So I think everything we have has some engineering into it (Isabel).

Again students recognised the place of design in engineering. This is also a critical component of technology education in the New Zealand Curriculum, with three strands devoted to the design and development of products and systems (Ministry of Education, 2017), however like construction none of the participants volunteered the connection to technology education.

Fifteen of the nineteen student teachers were able to recognise common ground between technology and engineering when specifically asked. Mike aptly articulated this. "Technology is related to engineering now, it's totally incorporated. You can't separate the two as far as I'm concerned" and Toni "Between technology and engineering? Oh, definitely. Understanding how things work and using their prior knowledge to apply it at a high level".

The first and most common of the three themes discussed in this paper is technology education as a 'Precurser to Engineering'. This was mentioned by seven of the participants and is exemplified below.

> I think technology the idea is that it leads on to engineering. So if you and I'm seeing this in a different way but I think perhaps a historical perspective is if a student went into technology there that is the pathway to go to engineering (Cody).

Stacey also illustrated this point by stating "I don't think that they realize it's engineering just yet". These findings were inline with William's (2011) views that there are close links between technology and engineering . It is heartening to know that a third of particpants were able to articlate clear links between technology and engineering, however also concerning that a further two thirds were not. As all students had undertaken technology as a part of their ITE programme before being interviewed, therefore the foundations of this disparity might indicate a lack of knowledge of technology education despite having engaged in a course, or a lack of understand of engineering practice or both.

The second theme to emerge from the data was 'Opportunities for Integration'- acknowledged through the mention of STEM (Science, Technology, Engineering and Maths). Currently in New Zealand engineering is not a part of the New Zealand curriculum (Ministry of Education, 2007), although some schools offer engineering programmes at senior secondary schools they tend to have a focus on mechanical construction. Three of the particpants recognised STEM as common ground between technology and engineering as Amy suggested.

> I think that's where STEM comes into play because you kind of really need those for engineering, I think …. you needed math but you also need to kind of understanding of science. So having that technology aspect, a kid might be interested or not, if you introduce them to technology that might be enough to go yeah OK engineering, sweet (Amy).

Amy recognised the integrating nature of technology. Her thinking was aligned with Snape and Fox-Turnbull's (2011, 2013) work on the relationship between authentic inquiry learning and student engagement. Amy's understanding of STEM indicates an interdisciplinary approach to education which C. Jones (2010) states is an approach that critically synthesises multiple disciplines, within which topics from more than one discipline can be taught in parallel. Within this approach students frequently work in groups and is very useful pedagogical approach for the teaching of technology education (Fox-Turnbull, 2012).

The third theme indicates misconceptions about technology education rather than engineering. One quarter of the participants described technology as the technological tools used in the engineering process, as exemplified by Lynne in her description of bridge development.

> What you would do to make it a bridge, you might do some background reading, look at what other people have drawn, their plans. You might need to look at some of the calculations that you have to do, and then you'll have to talk to your client, see what they want, and I think an architect will probably do the drawing first, and then they go to a structural engineer, who would help with making sure that the structure is safe. They'll definitely be doing calculator with the drawings at that point, and maybe there'll be some modelling. I'm not sure. Maybe on computer or you might actually make it out of materials, and then somebody else would have to approve it, and then you can make it. I don't know how correct that was (Lynne).

Lucy also indicated a 'tools' approach to technology when she stated "That's very important in order for kids to learn about engineering and all, they would need to know the technology behind it and the use of technology to even develop an idea for something". Stankiewicz (2004) states that many peoples' notions of technology are that of recent IT equipment, laptop computers, digital devices etc. The understanding of technology in technology education encompasses notions of intervention by design (Ministry of Education, 2007). The prevalence of this thinking was particular disappointing as all students had completed a course technology education based on the idea of technology as defined in NZC (Ministry of Education, 2007).

Conclusion

Determining whether primary teachers have accurate opinions of engineering practice and how they understand the links between technology education and engineering has the potential to assist student pathways into engineering. This study suggests an emerging need to develop understanding of engineering practice and how it links to technology as a necessary skill for future primary school teachers. To make explicit links between the two, teachers need to have deep understanding of the types and scope of engineering disciplines and a thorough understanding and well-informed practice in technology education, then subsequently make explicit links to technology education within ITE programmes.

Assessing the effects of educator influence offers potential to address the lack of diversity in Engineering through developing teachers' understanding and influencing their conscious and unconscious behaviours. It is critical that beginning teachers are cognisant of the impact they have on students' notions of careers and their ability to particpate in them. Best teaching practice suggests learning situating in authentic contexts is engaging and motivating for students (Fox-Turnbull, 2003; Wagner, 2008). One way that this may be done is to make links between school-based learning and students' possible future careers. This study reveals a lack of understanding of engineering and technology education from the majority of its particpants. The fact that one third of the particpants in this study were able to see some links between technology and engineering superficially looks to be good news for the technology education and engineering communities. However, given that these connections have sterotypical views of engineering at their roots and that two thirds of the paricpants could not see clear links is somewhat concerning. We know teachers influence early adolescence in career decisions (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001; Di Nardo et al., 2006; Low et al., 2005). We also know that sometimes the influence is inadvertant and possibly unconscious (Lamb et al., 2018; Low et al., 2005). We suggest that engineering professional bodies put considerable time and resources into better educating not only students but their teachers on the true and varied nature of engineering disciplines with accutate links to the school curriculum, especially technology.

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