Introduction

STEM education is argued to be vital to Australia's future prosperity (Office of the Chief Scientist, 2014). In the context of primary school education, STEM learning often focuses on science and mathematics without explicit reference to engineering. While there have been some studies conducted in the United States which have investigated primary-school-aged children's conceptions of engineers, there is a lack of research which has been conducted regarding Australian students' conceptions of engineers and engineering. Several studies in the United States have used a 'Draw an Engineer Test' (DAET) to capture primary students' thinking. The DAET is an adaptation of the 'Draw a Scientist Test' developed by Chambers (1983).

When used in the United States, the DAET has shown that students typically view engineers as performing one of five main roles. That is, they either build, fix, create, design or drive (Knight & Cunningham, 2004). Capobianco, Diefes-dux, Mena, and Weller (2011) describe their observations using the similar categories of, mechanic, labourer, technician and designer. For the first time in 2017 'Design and Technologies' will be a mandated component of the Australian Curriculum (ACARA, 2014) and will include primary-level assessment standards for design-based activities which involve engineering design processes. If Australian students display similar conceptions of engineering as American students, these conceptions will be at odds with aspects of the new Australian Curriculum and the general aims of promoting engineering through STEM education.

Purpose

The primary purpose of this study is to gather data regarding Australian primary school students' conceptions of engineers and engineering. Just as similar data gathered in the field of science (Symington & Spurling, 1990) has been used to guide teacher practice, this data may serve a secondary goal of helping frame engineering education in a primary setting. In science education, students' conceptions of scientists have been seen to affect levels of student participation in science, attitudes towards science and general scientific literacy (Brown, Grimbeek, Parkinson, & Swindell, 2004). Students' perception of engineers, even from the early years of primary school, may have a similar impact on participation in subsequent engineering education. Thus, if engineering processes are to be developed in primary schools by the 'Design and Technologies' component of the Australian Curriculum, then assessment of students' prior conceptions of engineering may be used to guide implementation of the curriculum.

This study occurs as part of a broader intervention (the ESTEME partnership project) designed to promote engineering in primary schools. The study also seeks to evaluate the utility of the adapted form of the DAET as a data collection tool as the intervention program develops.

Approach

An adapted Draw an Engineer Test (DAET) (Knight & Cunningham, 2004) and a Draw a Scientist Test (DAST) were administered in ESTEME partnership schools. There are seven Melbourne primary schools involved in the ESTEME partnership between primary schools, and the academic faculties of Education, Engineering and Science at the University of Melbourne. The DAET and DAST were administered to children whose teachers are involved in the partnership across the seven schools. This resulted in 154 DAETs being gathered from students from foundation level (first year of primary school) to year 6.

Students were asked to draw a picture of an engineer engaging in engineering and write a sentence explaining their picture. Younger children were assisted writing about their picture by their classroom teacher. Critics of the DAST (upon which the DAET is based) have

claimed that when asked to ‘draw a scientist’, students may believe that they are being asked to draw the publicly accepted stereotype of a scientist (Boylan, Hill, Wallace, & Wheeler, 1992; Symington & Spurling, 1990). Therefore a single drawing does not represent their actual understanding and knowledge. When asked to draw a second scientist, students may show an understanding of what scientists do beyond a stereotypical image in that, while they may draw a stereotypical chemist in the first picture, the second picture may show another type of scientist (e.g. an astronomer, or a marine biologist) which demonstrates that they are aware of conceptions of scientists beyond common stereotypes (Cheng, 2013). Hence, when the DAET was deployed in this study, students drew and annotated a second engineer in order to investigate whether the first picture would reflect a stereotype of engineers while the second picture might demonstrate a conception of engineers beyond a stereotype. Students were also asked to draw a picture of a ‘person’ before they drew an engineer. This modification of the DAET was also guided by research using the DAST which has argued that if features such as ‘crazy hair’ (common in stereotypes of scientists) appear in students’ pictures of scientists, then a baseline picture of a person is needed to ascertain whether this feature is indeed indicative of the student’s perceptions of a scientist as it may be the case that they just draw all people with crazy hair (Cheng, 2013).

Once collected, illustrations were analysed and coded for common features in both their pictures and in the accompanying explanatory sentence. Analysis of pictures entailed identifying specific features and drawn items in each picture of an engineer which were not present in the student’s picture of a person. Each of the four authors coded the data independently before cross referencing and refining the coding scheme. The drawings of some students could not be consistently coded by the four authors because – particularly with younger students – the image produced could not be clearly identified by the coders. In the case of all 16 drawings collected from a foundation classroom (of 5-6 year olds) and a small amount of drawings across the other grade levels collected, only the explanatory sentence could be coded (which had been dictated to the classroom teacher who wrote it down for the foundation students).

Explanatory sentences were coded according to words used. Again, four coders independently coded the sentences before refining the coding scheme. Because students were asked to draw an engineer engaging in engineering, explanatory sentences tended to contain a verb which described the action depicted in the picture. This allowed coders to distinguish between responses where certain words – such as ‘build’ – were being used as verbs (e.g. engineers build machines) or nouns (e.g. engineers design buildings).

Results were then broken down by year level to see if students’ perceptions of engineers change as they get older. Students’ first drawing was then compared to their second drawing to ascertain if, like drawings of scientists, there are some stereotypical conceptions of engineers that may feature more prominently in students’ first attempt to draw an engineer. The researchers compiled a list of items which they thought students might associate with engineering and, therefore, might be represented in their drawings. Some of these items (such as trains) had featured in previous studies using the DAET (Knight & Cunningham, 2004). Others were based on the researchers own speculations. Given the increased representation of engineers as creators and users of sci-fi gadgets in children’s media (Marvel’s *Iron Man: Armoured Adventures*, for example), it was hypothesised that this conception of an engineer might be present in the data. Finally, the research team was aware that a number of students in the sample had parents who were engineers. Hence, when coding, any explicit reference students made to their parents’ work was noted so that the conceptions of the children of engineers could be contrasted to the general conceptions displayed.

While this study focuses on the results of the DAET, some comparisons were also made to the DAST that was administered to students within the same month as the DAET. The main point of comparison was whether students were able to draw a significantly different second representation of an engineer or scientist from their first picture.

Results/ Discussion

Based on coding of 272 pictures and text comments students primarily drew engineers as using tools (37.9%) while fixing (21.0%) cars (26.5%). The second most common theme involved engineers in safety gear (14.7%) on building sites (11.0%) using construction tools. In their text comments, students primarily use the verbs 'fix/repair' (44.1%) although a smaller section of students use the verb 'make/build' (15.0%) and a very small proportion of students used the verbs 'plan/design' (4.4%). The most frequently used nouns were 'car' (32.4%) and 'buildings' (10.3%). Figure 1 provides an example of the most common conception of an engineer in the collected data – compared to the student's picture of a 'person', an engineer has tools and is fixing a car. Figure 1 also provides an example of how many students second drawing of an engineer represented an engineer engaged in the same activity as the first drawing. When asked to draw two scientists, 81% of students' second scientist was engaged in a significantly different activity than the first (e.g. picture 1 may have been a chemist while picture 2 was an astronomer). When asked to draw an engineer, only 67.8% of students' second drawings did not replicate the conception of engineers represented in the first picture. Hence, students' conceptions of engineers lacked the variety and diversity of their conceptions of scientists.

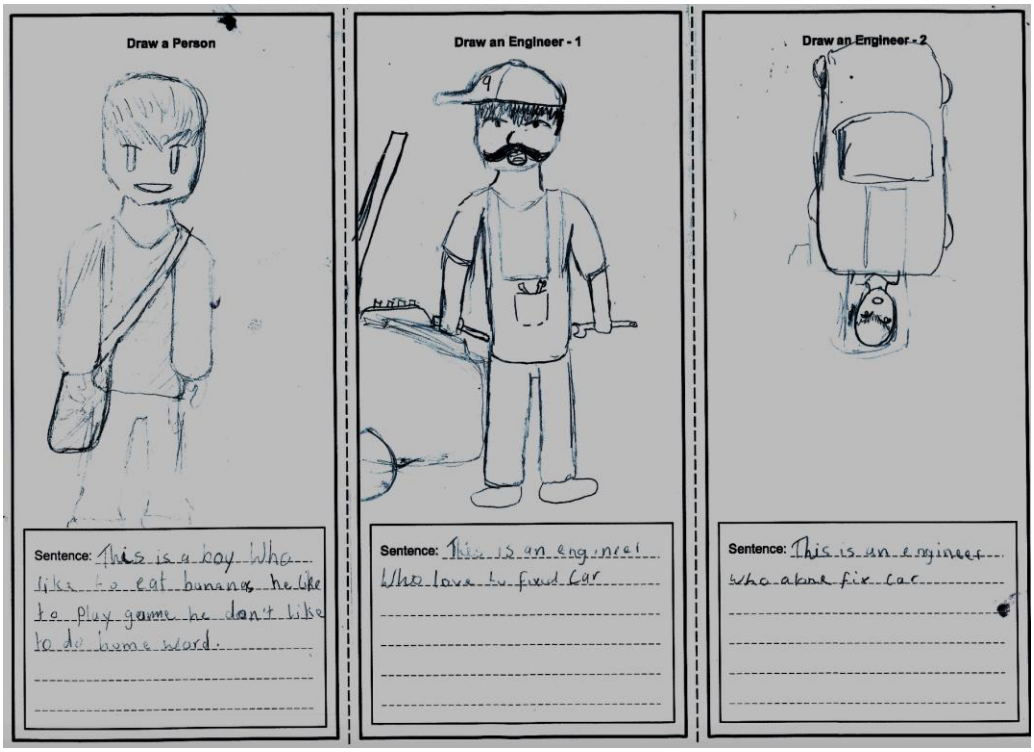

Figure 1: Typical student representation of an Engineer

Students' representations of engineers appear to change over the course of their primary school education. Table 1 shows the three most common types of drawings in each of the year levels in which data was collected (all schools involved use 'composite' classes where, apart from Foundation, two year levels work together in the same class). It is evident that students in their Foundation year, are far more likely to have a completely unrelated conception of engineers and engineering (i.e. when asked to draw an engineer they draw a picture of their dog). Few students in years 1 and 2 display completely unrelated conceptions. By year 3 and above these kinds of unrelated representations are uncommon

(<1%). When Foundation students' drawings of scientists were compared to their drawing of engineers, the rate of 'unrelated' representations dropped. Only 6.3% of Foundation students drew something unrelated (e.g. a picture of their pet dog) when drawing a scientist, whilst 43.8% of students drew something like this when asked to draw an engineer. This suggests that children's conceptions of scientists may develop earlier than their conception of engineers and that the term 'engineer' may not be in the vocabulary of many 5 to 6 year old Australian children.

Table 1: Most common representations of engineers by year level

	Foundation (5-6 y.o.)	**1/2 (6-8 y.o.)**	**3/4 (8-10 y.o.)**	**5/6 (10-12 y.o.)**
Most Common	Unrelated to engineering (43.8%)	Fix cars (61.8%)	Fix cars (29.7%)	Fix cars (49.1%)
Second most common	Fix Cars (18.8%)	Unrelated to engineering (14.7%)	Construct buildings (20.3%)	Construct buildings (11.1%)
Third most common	Construct buildings (6.3%)	Use electronics (10.3%)	Drive vehicles (7.8%)	Design or make plans (10.2%)

Table 1 also shows that fixing cars remains a common conception across all grade levels. Interestingly, designing or making plans (perhaps the most accurate of perceptions of the work of engineers) only appears as a significant component of thinking at the year 5/6 levels.

Table 2: Items which featured in children's first picture more than the second

Item	**Proportion of representations in the first picture**	**Proportion of representations in the second picture**
Tools	60.2%	39.8%
Fixing	57.9%	42.1%
Buildings	57.7%	42.3%
Cars	56.9%	43.1%

Table 2 highlights students' tendency to initially represent their engineers as either mechanics who fix cars with tools or labourers who build with tools. In the second representation created by students, these themes remained dominant, however generally they represented a lesser proportion of the overall sample. This suggests that these two representations are the stereotypical representations of engineers in most students' minds. Although, unlike students' representations of scientists, many students (32.2%) second picture replicated these stereotypical images suggesting that they only have one, stereotypical conception of engineers.

Prior to data collection, it was predicted that a significant number of students may depict their engineers driving trains, fixing or creating electronic devices or gadgets and designing or building bridges. Knight and Cunningham (2004) reported 9% of students in their study drew engineers engaging in train driving, yet as shown in Table 3, only 1.1% of students

represented anything related to trains in the data collected in this study. An important aspect of this study is that it is located in an Australian setting. Therefore, subtle differences in the ways Australian students and students from the United States use language and convey meaning may have led to differences in results.

Table 3: Engineering-related items which were not frequently represented

Item	Frequency of representation
Drawings/plans	2.6%
Driving	1.8%
Mechanical devices	1.8%
Electronics	1.8%
Bridges	1.8%
Gadgets	1.5%
Trains	1.1%
Oil and gas	1.1%
Roads	0.7%

A much smaller group of students included terms such as ‘design’ in their explanatory sentences. When they did, their accompanying pictures showed a range of activities including designing roads, robots and chemicals. These pictures were also more likely to show engineers as working in offices, at desks with computers.

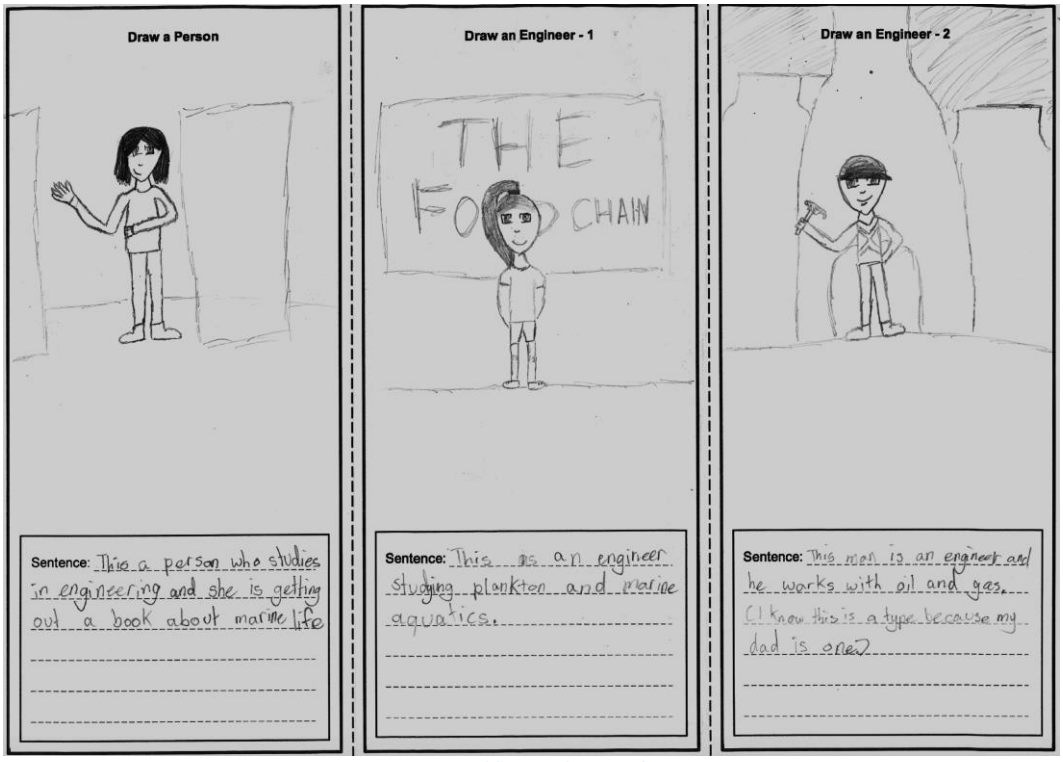

Figure 2: Engineer Created by Student with Engineer Parent 1

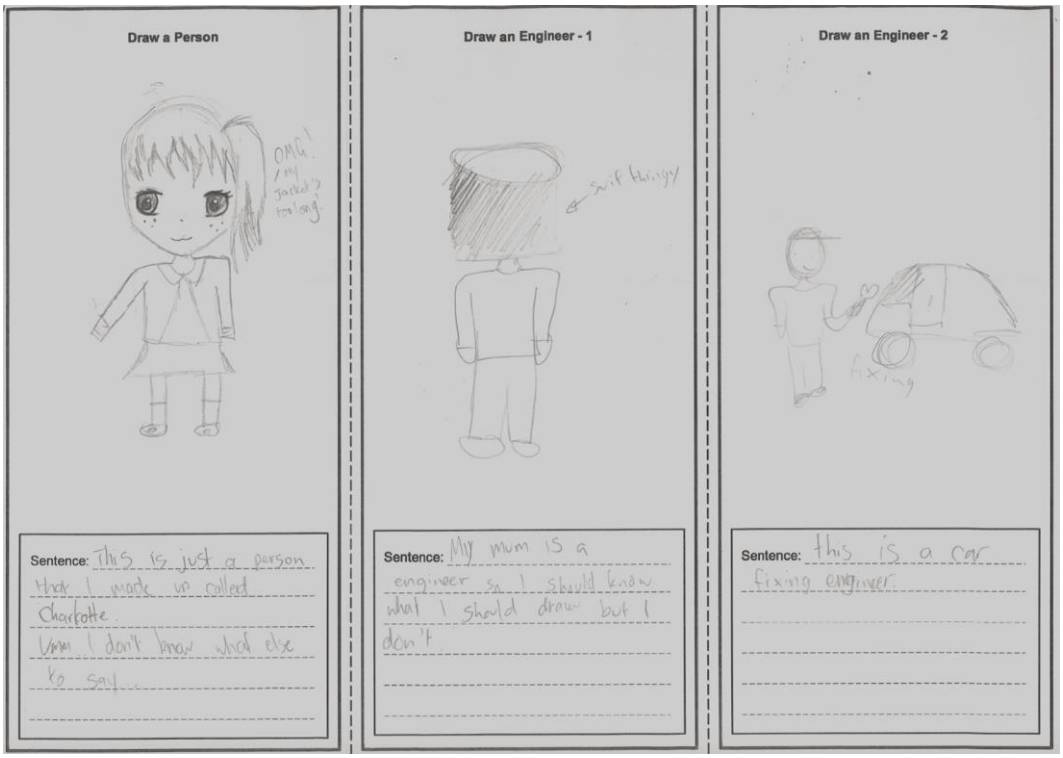

Figure 3: Engineer Created by Student with Engineer Parent 2

Only five students identified that their parents were engineers. Figure 2 provides an example where the child of an engineer displays a conception of engineering which does not match the common stereotypes displayed more generally. In contrast, Figure 3 provides an example of a child of an engineer displaying the common stereotyped view of engineering. They provide the following caption alongside one of their images; *My mum is an engineer, so I should know what I should draw but I don't.* This statement was unexpected and indicates that even when students have close relationships with family or friends who work as engineers it can not be assumed that their knowledge of the occupation will not be stereotypical.

Figure 1: Design-focused representation of an Engineer

Figures 4 provides an example of the less common depiction of engineers as designers. While this representation also entails working with cars, in this case the engineer is drawing plans in order to design the car. Across all year levels, this depiction of engineers was present in 4.4% of the drawings and only occurred with students who were grade 3 or older.

Recommendations, Implications & Conclusions

The results of this study suggest that Australian primary school students have a limited understanding of what engineers do. This limited understanding – primarily the idea that engineers fix cars – may form a barrier to efforts to incorporate engineering principles in the 'Design and Technology' component of the Australian Curriculum. More broadly, engineering skills are being promoted as an important part of STEM education (Office of the Chief Scientist, 2014). Yet, primary school students do not associate engineering with the design and problem solving components of the curriculum. Hence, one may ask, where is the 'E' in STEM in Australian primary schools?

Studies based in the United States have shown a majority of students perceiving engineers as builders (Knight & Cunningham, 2004). Our study found that Australian students' stereotypical conceptions of engineers were different – train driving was far less prominent and fixing cars was more prevalent than construction work. Perhaps, the cause of these differences lie in language; in Australia, train drivers tend to be referred to as 'train drivers' rather than 'engineers' hence the association with engineering is less. Perhaps, when faced with an unfamiliar word, students base their conceptions on related words and hence, in Australia, the prevalence of the stereotypical view that engineers fix cars can be explained by the similarity of the words 'engineering' and 'engine'.

Like American students, Australian students generally had an extremely limited understanding of the roles and variety of work that constitute engineering and that engineers participate in – more limited than when asked about the work of scientists. If the current interest in STEM education is going to adequately represent the 'E' in STEM then, like science education in the past, a beginning step may be to broaden students' conceptions of engineering. The data presented in this study suggests that, even if a design process was to be used in primary schools, it's unlikely that students would be able to associate it with engineering given their current stereotypical views.

Further research should address how Australian children's conceptions of engineers and engineering can be broadened and more accurately reflect the work that engineers do. The data presented in this study represents baseline data for a larger study which aims to test whether students' conceptions of engineers can be changed though a community partnership project between primary schools and the University of Melbourne. The project partners primary school teachers with engineering and education academics to help schools develop STEM-focused unit plans for partnership schools which explicitly highlight the work of engineers. The University also uses 'engineering days' to bring grade 5 and 6 students into engineering labs to promote engineering to students. The position taken in this project is that productive STEM education would begin to build students' conceptions of engineering from their Foundation year of primary schooling. The current study can be used to guide this development as the data presented suggests that in Foundation to Year 2, it cannot be presumed that students will have formed any representation of engineering given the proportion of students who drew pictures which were not related to engineering. From Years 3 to 6, a small proportion of students were able to associate engineering with design – the primary curriculum area which, in the authors' opinion, captures elements of engineering design process. Hence, STEM education at these levels may be able to develop students' conceptions of engineers beyond the stereotypes of mechanics and construction workers, towards conceptions that include design. Just as science educators have argued that primary-aged children's perceptions of science are related to their productive participation in

science at school and university (Cheng, 2013), changing students' perceptions of engineering may also have a relationship to their participation in school and university based engineering education. As Australian education policy continues to promote STEM education from the early years of schooling, the results of this study may also help ensure that the 'E' in STEM does more than provide a vowel for the acronym – by knowing how young children are likely to think about engineering, engineering-focused educational activities can explicitly address and transform the kinds of stereotypes that students hold.

References

ACARA. (2014). *The Australian Curriculum V5.2*. Australian Curriculum and Reporting Authority Retrieved from http://www.australiancurriculum.edu.au/.

Boylan, C. R., Hill, D. M., Wallace, A. R., & Wheeler, A. E. (1992). Beyond stereotypes. *Science Education, 76*(5), 465-476.

Brown, K., Grimbeek, P., Parkinson, P., & Swindell, R. (2004). Assessing the scientific literacy of younger students: Moving on from the stereotypes of the Draw-A-Scientist-Test. In Bartlett, B., Bryer, F. & Roebuck, D. (Eds), *Educating: Weaving research into practice* (pp. 144-152). Nathan, Qld: Griffith University.

Cheng, H. (2013). What can we learn from Chinese and Australian primary school students' perceptions of scientists and science learning? In C. Redman (Ed), *Sucessful science education practices,* New York: Nova.

Capobianco, B. M., Diefes-dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *Journal of Engineering Education, 100*(2), 304-328.

Knight, M., & Cunningham, C. (2004). *Draw an Engineer Test (DAET): Development of a tool to investigate students' ideas about engineers and engineering.* Paper presented at the 2004 American Society for Engineering Education Annual Conference and Exposition, Salt Lake City, Utah.

Office of the Chief Scientist. (2014). *Science, Technology, Engineering and Mathematics: Australia's Future*. Canberra: Australian Government.

Symington, D., & Spurling, H. (1990). The 'Draw a Scientist Test': Interpreting the data. *Research in Science & Technological Education, 8*(1), 75-77.

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