A Comparison of Swedish and Irish Secondary Students' Conceptions of Engineers and Engineering using the Draw-an-Engineer Test

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Dr Jeffrey Buckley received his PhD from KTH Royal Institute of Technology, Sweden, in the area of spatial ability and learning in technology education. He is a qualified post-primary teacher of Design and Communication Graphics and Construction Studies. He is currently a post-doctoral researcher in engineering education in KTH Royal Institute of Technology, Sweden, and Athlone Institute of Technology, Ireland, and is also a member of the Technology Education Research Group (TERG). His main research interest is in how people learn. He is particularly interested in how cognitive abilities such as spatial ability affect students capacity to learn, and how levels of prior knowledge impact on further learning. Jeffrey is also interested in inclusivity in engineering and technology education, particularly in relation to stereotypes and misconceptions that people may have about technical subject areas.

Dr. Lena B. Gumaelius, KTH Royal Institute of Technology

Dr Lena Gumaelius has a background as a researcher in Biotechnology, in which field she still teaches undergraduate students at KTH. (Lena got her Master of Science in chemistry 1993 and her PhD in Environmental Microbiology in 2001.)

In parallel with her research, she worked for several years with development of experiments for students at House of Science. In 2006 Lena became the director of House of Science, which she remained until 2012. House of Science is a university based Science centre with about 40 000 visitors were the goal is to stimulate high school students' interest for the natural sciences, math and technology. During these years Lena developed her pedagogical skills and competence in the pedagogic field and besides leading the activities she organised pedagogical training for teachers, pupils and university students.

Between 2011 and 2016 Lena was the head of the new Department of Learning at the School of Education and Communication in Engineering Sciences (ECE), KTH. Lena was then responsible for building up a new strong research environment in engineering and technology education, K-12 to university level.

2016-2017 Lena was the Dean at the ECE school at KTH. As this School was merged with another School in 2018, from January 2018 Lena has a research position as an Associate professor at the ITM school at KTH.

Mr. Tomás Hyland, University of Limerick

Tomás is currently hired as a teaching assistant on the initial technology teacher education programmes where he has worked since graduation. He is currently undertaking a PhD in the School of Engineering at the University of Limerick under the supervision of Dr Seamus Gordon, Dr Niall Seery and Dr Jeffrey Buckley. Tomás' PhD research focuses on mainly on the areas of learning, cognitive load theory and spatial cognition. Tomás has a particular interest in conducting school based research to gain insight into authentic classroom activity and learning. He is conducting research with both post-primary and university students looking specifically at if having elevated spatial skills reduces the cognitive load associated with learning new fundamental Engineering/Technology concepts.

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Arnold Pears received his BSc(Hons) in 1986 and PhD in 1994, both from La Trobe University, Melbourne, Australia. He occupied positions as lecturer and senior lecturer at La Trobe University between 1991 and 1998. In 1999 he was appointed as senior lecturer at Uppsala University, Sweden. He was

awarded the Uppsala University Pedagogy Prize in 2008, and appointed as Associate Professor of Computing Education Research in May 2011. Roles at Uppsala University include appointment to the University Academic Senate, Programme Director for the IT Engineering programme, member of the selection committee for the Uppsala University Pedgogy prize and as member of the educational advisory board of the Faculty of Technology and Natural Sciences.

He has a strong interest in teaching and learning research in computer science and engineering, and leads the UpCERG research group in computing and engineering education research at Uppsala University. He has published more than 40 articles in the area internationally, and is well known as a computing education researcher through his professional activities in the ACM, and IEEE. In the IEEE he serves as a member of the Board of Governors of the IEEE Computer Society, where he is active in the Education Activities Board, serving also on the steering committee of the Frontiers in Education Conference and as Chair of the newly established Special Technical Community (STC) for Education. In addition he is a Director of CeTUSS (The Swedish National Center for Pedagogical Development of Technology Education in a Societal and Student Oriented Context, www.cetuss.se) and the IEEE Education Society Nordic Chapter. He as a reviewer for a number of major journals and conferences, including the Computer Science Education Journal (Taylor and Francis), the ACM SIGCSE and ITiCSE and Koli Calling International Computer Science Education conferences.

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Abstract

Women are significantly underrepresented in engineering and engineering related disciplines. One area where this is clearly illustrated is in the percentage of females enrolled in higher education engineering courses. The 2016 data on enrolment by field from the Organization for Economic Co-operation and Development (OECD) shows that the maximum percentage of female enrolment in "engineering and engineering trades" education at Bachelors, Masters, and Doctoral level in OECD countries is 28.33% in Sweden. As this form of education is likely to lead to a career in an engineering related field, there is a clear need to understand the factors which influence female students' decisions to enroll in higher education engineering courses.

There are many influences on students' choices to pursue specific career paths. For example, how students conceive a particular discipline or career will influence this decision, as what they believe it to involve will likely affect their interest in engaging with it. In engineering, students often have misconceptions regarding what it means to be an engineer and the Draw-an-Engineer Test (DAET) has frequently been used to investigate these misconceptions.

Studies using DAET have found that young students typically conceive engineers to be male, with the majority of male students typically representing engineers as male, but, with female students drawing more frequent but still relatively small proportions of female engineers. However, at least with the original "Draw a" instrument, the Draw-a-Scientist Test (DAST), children's drawings of scientists have been found to be becoming more gender diverse over time.

In this study, the DAET is used in a comparative study between Sweden and Ireland. These countries were selected as according to the 2016 OECD data on higher education enrolment, Sweden has the highest representation of female engagement with engineering in higher level education (28.33%), while Ireland has one of the lowest (14.13%). The study cohort (n_{total} = 513; $n_{Ireland}$ = 302; n_{Sweden} = 211) in the context of both countries includes students who are approximately 15 years old. This age is of cultural significance in both countries as students are at a juncture in second level education where they must make a choice on what they will study at upper secondary level, which will consequently have an impact on their decision on what to study should they choose to progress to higher level education. Results are presented in relation to participants engineering stereotypes in terms of gender and the nature of engineering activities, and also in terms of their level of interest in engineering. Importantly, the results indicate that in order to understanding engineering stereotypes and young people's interest in becoming an engineer, the complex relationship between a student's gender, cultural context, and conception of engineering must be considered.

Introduction

Female representation in engineering

Gender representation in higher level engineering education is predominantly inequitable. At a national level, 2016 data from the Organization for Economic Co-operation and Development (OECD) indicates that the percentage of females enrolled in "engineering and engineering trades" education at bachelor's, master's and doctoral level ranges from 11.54% to 28.33% in OECD countries [8] (Figure 1). At a field level, taking 2017 data from the US as an example, Yoder [9] demonstrates that the percentage of females earning degrees at each of these levels varies from approximately 10-50%. However, of the 23 fields included in Yoder's report [9], gender equity, considered as being 40-60% representation, is only observed in environmental (50%) and biomedical (44%) engineering at bachelor's level, environmental (45.7%), biomedical (42.9%), and architectural (40.7%) engineering at master's level, and environmental (48.7%) engineering at doctoral level.

This lack of female representation in engineering education at higher level is troubling for many reasons. For example, for engineering as a discipline the lack of female representation confers a loss of talent. Additionally, in terms of society, the gender disparity indicates the potential existence of barriers restricting women's access to engineering. Wang and Degol, drawing on a thorough literature review, outline six explanatory factors for the lack of female representation in math intensive science, technology, engineering and mathematics (STEM) disciplines [10]. Specifically, they describe the underrepresentation of women in STEM as a result of a complex interaction between (1) absolute ability differences between males and females, (2) relative ability strengths of males and females, (3) career preferences, (4) lifestyle preferences, (5) field-specific ability beliefs, and (6) gender stereotypes and biases. This paper contributes primarily to this discourse around stereotypes and biases, both in terms of gender and engineering stereotypes. However the interpretation and implications of this research must be considered within the complex interaction outlined by Wang and Degol [10].

Gender stereotypes and bias

In their review of influential factors leading to women's underrepresentation in math-intensive STEM disciplines such as engineering, Wang and Degol [10] highlight the continued discourse surrounding the impact of discrimination. Specifically, they identify the need to acknowledge the effects of covert as well as overt sexism when considering female representation [11], [12] as when overt sexism is solely considered it can lead to the conclusion that gender based discrimination is a historic and not a contemporary explanation for the underrepresentation of women in math-intensive STEM disciplines [13]. Furthermore, covert sexism can be considered to be non-detrimental [14] even though it is demonstrably present, and undoubtedly shapes males and females career trajectories [10]. Similarly, gender stereotypes have been found to influence career trajectories, with effects being observable at young ages. For example, math anxiety in female kindergarten teachers has been associated with their female students endorsing negative gender-mathematics stereotypes [15], [16] with a similar association existing between parental gender-mathematics beliefs and their children's mathematics ability beliefs [17], [18].

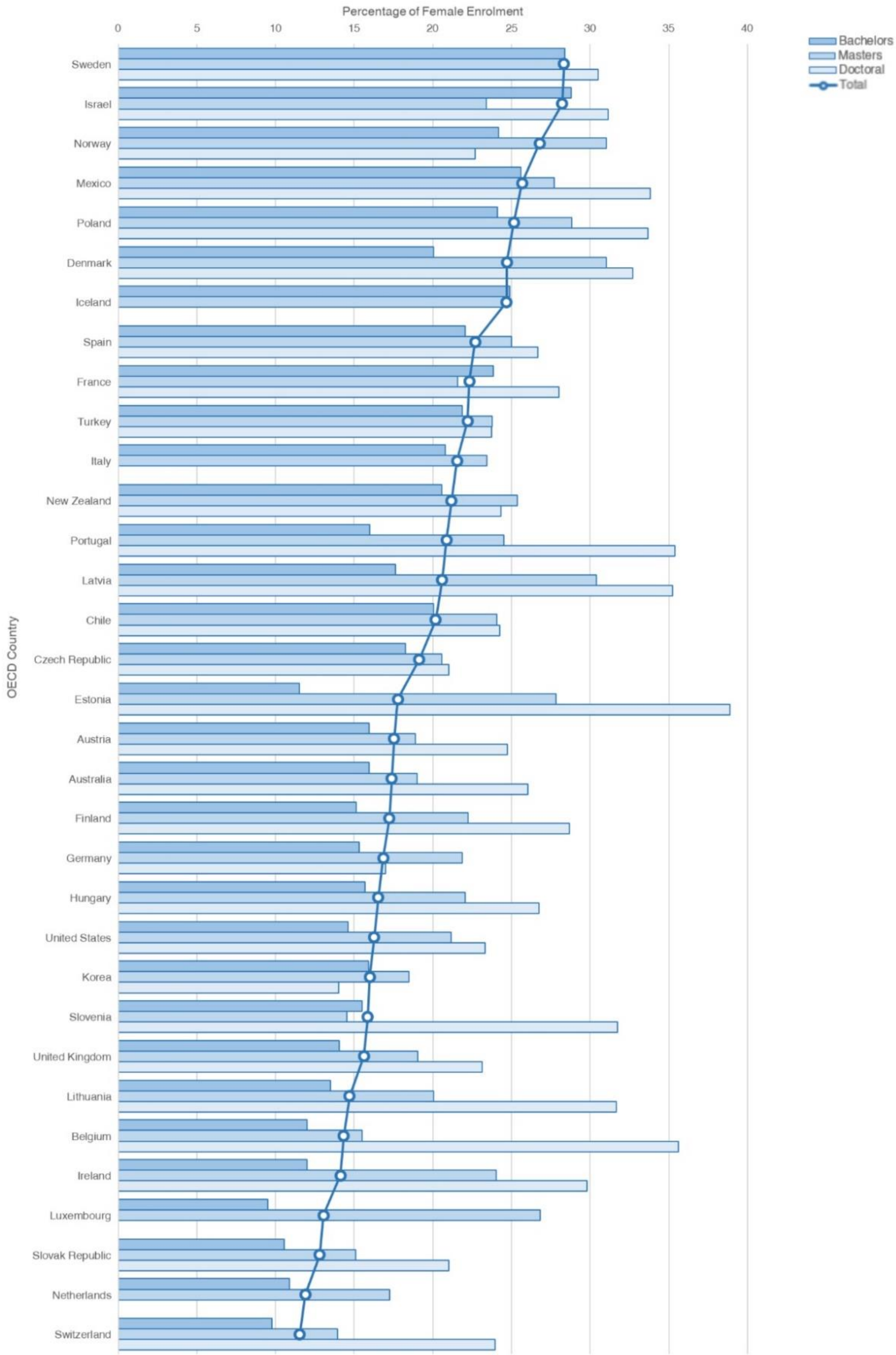

Figure 1. 2016 data on the percentage of female enrolment in higher education ‘engineering and engineering trades’ disciplines in OECD countries [8]. Complete data was missing from Canada, and doctoral data was missing from Iceland, Italy, Luxembourg and The Netherlands.

As such interactions can have the negative consequence of fostering a false belief in young women that disciplines such as engineering are not accessible or appropriate for them, even though this outcome is often unintentional, it is paramount that this stereotype and stigma is not perpetuated.

Approaches to increase female representation in engineering

Wang and Degol [10] provide policy and practice recommendations with associated research for the improvement of gender equity in math-intensive STEM disciplines. These include to:

1. Focus on ability enhancement but also interest enhancement
2. Intervene early to cultivate interest in math and science
3. Break down stereotypes about women and STEM
4. Emphasize effort and hard work instead of talent
5. Add more storytelling to STEM learning
6. Communicate the relevance of a STEM degree to real-world applications
7. Providing more female role models for girls and women
8. Accommodate women’s familial obligations in the workplace

Similar to their position of factors which can explain female underrepresentation, these proposals also relate to each other. Of particular relevance here is the recommendation to break down stereotypes about women in STEM which, for example, appears to have a complex association with the provision of more female role models. Some evidence points to positive effects of female role models [19], other evidence indicates no effect [20], [21], and other evidence indicates a positive effect, no effect or a negative effect depending on the discipline area [22]. As a result of situations such as these with contradictory evidence, there is a need to ensure that research is nuanced enough to support meaningful translation into practice, while also being broad enough to consider potential moderators and far-transfer effects. In practice this calls for instruments that are appropriate for study cohorts of interest and which can provide meaningful information, and for engineering stereotypes, the Draw-an-Engineer Test (DAET) shows potential, particularly with school aged participants.

The Draw-an-Engineer Test

The DAET was developed as an adaption of the Draw a Scientist Test (DAST) [3] by Knight and Cunningham [2]. Specifically, it requires participants, in a prescribed period of time, to “draw an engineer doing engineering work” [6]. Typically, this activity is then followed by a series additional complementary questions [23], [24] however there is no consistently adopted protocol of questions within the literature. One of the attributes the DAET is credited for is its capacity to espouse stereotypes participants assign to engineers [2], [6], [23], [25], a capacity also attributed to the DAST in terms of scientists [3], [4]. However, this has been previously contested as multiple models of scientists could be held by participants but these instruments only request one [26], while others argue that in asking for only one image a stereotype is likely to be evoked [25]. Understanding such stereotypes is particularly important as it can contribute to the knowledge concerning female underrepresentation in STEM, and ambiguous disciplines such as engineering are relatively susceptible to stereotypical ascriptions [27]. Based on the idea that the

DAET permits certain types of stereotypes to be discerned it has become increasingly popular, with multiple studies adopting it in recent years [23], [28]–[32], and indeed the popularity of “Draw-a” instruments has resulted in their use for other occupations such as science teachers [33] and computer scientists [7].

The DAET has been used with a variety of different participant demographics including high school students [34], university students [35] and P-12 teachers [36] in Mexico, primary education students [23] and gifted secondary school students in Turkey [32], and elementary school, [37], middle school [5], and gifted students in the US [38]. The two most prominent findings presented in DAET studies are the gender stereotypes participants associate with engineers, and the activity stereotypes associated with engineers. In relation to gender stereotypes, when controlling for drawings where gender was not discernable, studies have found that approximately 80-100% of male participants draw male engineers and approximately 1-20% draw female engineers, whereas approximately 50-75% of female participants draw male engineers with approximately 25-50% drawing female engineers [2], [6], [23], [36]. In other studies, only the total amounts of the genders of drawn engineers is reported. When controlling for drawings where gender was not discernable, these studies have reported that approximately 70-90% of drawn engineers are depicted as males with 10-30% being depicted as females [5], [32], [35], [39].

With respect to the activities typically associated with engineers, substantial work has been invested in approaches to assist in coding and analyzing this data. Initial work analyzed this data in terms of the verbs associated with engineering. These included terms such as “builds”, “fixes”, “creates”, “designs”, “drives”, “improves”, “calculates”, “invents”, and “studies” [2]. This then evolved to also include an associated subject being attached to the verbs such as “repair cars”, “install wiring”, and “drive machines” [25]. Perhaps the most significant development in this process was made by Diefes-Dux and colleagues where, over a series of studies, they created and validated the “INSPIRE DAET Coding System” to support more systematic analysis [6], [31], [37], [40]. Their coding system allows for drawings to be coded in terms of the people included, objects, system, environment, disposition, and level of sophistication. In addition, as this requires a substantial body of work, a second more concise coding system was created which only requires the coding of drawings in terms of how the engineer was conceived based on the type of activity being represented in the picture [41]. The purpose of this second coding system was to develop a simpler and more viable option to assess the sole construct of what engineers do. It allows the participants conceptions of engineers to be coded into the following categories:

- Designer: Designing or improving objects or processes, usually portrayed by drawing plans or performing specific parts of the engineering design process, an implied client or public use is intended
- Technician: Computer or electronic technician portrayed by a person fixing something electronic
- Design/Create single: Hobbies, crafts, and designs for personal use or making one object for a specific person

- Tradesman: Carpenters, plumbers, welders, etc. where a person is fixing something that is not mechanical
- Mechanic: Fixing a vehicle, engine, machine or something else that is mechanical
- Laborer/Builder: Building houses, roads or buildings through physical labor and other forms of manual labor not covered in other categories
- Driver: Drives or operates any type of vehicle including, but not limited to, cars, trains, trucks and airplanes
- Object/Engine: A person is not drawn and an object is intended as the "engineer"
- Factory/Make quantity: Factory workers or individuals making a quantity of an item without the notion of design or process indicated
- Other professions: Teachers, lawyers, doctors, policemen, scientists and other professions
- Other/None: Student was off-task or drawing is not discernable

Aim and Research Questions

The goal of this study was to augment the literature on engineering stereotypes within the wider context, with specific focus on addressing the underrepresentation of females. Considering the varying levels of representation across the OECD countries (Figure 1), this study aimed to compare engineering stereotypes in two countries, one with a relatively high level of female representation and one with a relatively low level of female representation, using the DAET. Additionally, it was of interest to study participants at a time point when they were making education decisions with respect to areas of study as these decisions are likely to impact their career trajectory by influencing higher level course selection. Finally, it was important that participants in both countries were of a similar age and gender distribution to allow for meaningful comparisons. Based on these criteria, Ireland and Sweden were selected as comparative countries. Ireland has a total of 14.13% female representation in engineering and engineering trades education at bachelor's, master's and doctoral level, the 5th lowest of the OECD countries, whereas Sweden has 28.33% which is the highest (Figure 1). In Ireland, students in 3rd Year are at approximately the age of 15 and are at the end of lower post-primary education. At the end of 3rd Year they make the transition to upper post-primary education. At this time, they make subject selections which they will be examined in at the end of post-primary education which has a direct relationship with their matriculation to higher level education. In Sweden, students finish compulsory education in Year 9 at approximately the age of 15 where they have had little choice in terms of what they study. They then progress into upper secondary school where they enter different programs based on their own interest and eligibility as dictated by their Year 9 grades.

Therefore, considering Irish 3rd Year and Swedish Year 9 students as comparative groups, the research questions guiding this study were:

1. What are the differences in gender-engineering stereotypes between Irish 3rd Year and Swedish Year 9 students?
2. What are the differences between Irish 3rd Year and Swedish Year 9 students' conceptions of engineers?

3. What are the differences between Irish 3rd Year and Swedish Year 9 students' levels of interest in becoming an engineer?

Additionally, in addressing each of these questions, the effects of within and between country participant gender were considered.

Method

Participants

In Ireland, from the years 2016-2018 just less than 62,000 students completed the Junior Certificate each year [42]. This is a national examination which occurs in 3rd Year, indicating that nationally there are approximately 62,000 3rd Years students every year. A sample size of 382 is therefore needed to achieve a 95% confidence level with a 5% confidence interval. In Sweden, approximately 111,000 students were in Year 9 for the academic year 2017/18, with approximately 125,000 students in Year 1. Considering the impending increase, taking 125, 000 as the population size, a sample size of 383 is needed to achieve a 95% confidence level with a 5% confidence interval. Data collection in the project reported on in this paper is currently still ongoing with the aim of collecting data from 400 Irish 3rd Year students and 400 Swedish Year 9 students. The results reported in this paper reflect the current stage of data collection ($n_{total} = 513$) and come from five random Irish schools and five random Swedish schools. Participants from Ireland ($n_{Ireland} = 302$) had a mean age of 14.63 (SD = 0.54) and comprised of 136 males, 149 females, 9 participants who identified as other genders, and 8 participants who chose not to disclose their gender. Of the Irish participants who identified as genders other than male or female, only one chose to specify, identifying as femfluid. Participants from Sweden ($n_{Sweden} = 211$) had a mean age of 14.99 (SD = 0.38) and comprised of 99 males, 98 females, 8 participants who identified as other genders, and 6 participants who chose not to disclose their gender. No Swedish participant who identified as a gender other than male or female chose to specify what they identified as. Participation was voluntary, and no compensation was given to students who participated.

Materials

The DAET was the primary instrument used in this study. The format was identical to that of Capobianco, Diefes-Dux, Mena and Weller [6] in that it consisted of an A4 sheet of paper with the instruction "In the space below, draw an engineer doing engineering work" and an empty space (7 inches × 7 inches) below for this activity. Accompanying this sheet of paper was a written survey which was provided after the completion of the drawings. In accordance with Capobianco, Diefes-Dux, Mena and Weller [6], participants were asked to provide a written response to the question "What is your engineer doing?" and aligning with Fralick, Kearn, Thompson and Lyons [5], questions regarding personal information and work setting were also asked. This included the questions "Is your engineer male or female?", "What age is your engineer?" and "Where is your engineer working?". A 5-point Likert item was provided asking participants "How interested are you in being an engineer?" on a scale from "Not at all interested" to "Very interested". Additional questions were also included, however, the results of these are not reported on in this paper. These additional questions concerned what engineers do in general, participants' post-school career interests, parent/guardian occupations, and the genders of the participants' current school teachers. The complete instrument is located in Appendix A. As the participants were a mixture of native English speakers and native Swedish speakers, Irish participants received an English version of the survey while Swedish participants received an alternate version which had been translated verbatim into Swedish.

Procedure

Participants were recruited through invitations for participation being sent to schools. In Ireland, letters containing information regarding the study and the complete survey were sent to school management of a random sample of schools directly by the researchers. In Sweden, the science educational center "Vetenskapens Hus" (English translation: House of Science) managed the recruitment of schools. As a large number of Swedish teachers and students attend educational courses at Vetenskapens Hus, teachers were directly informed while there about the study and asked to volunteer to participate. As previously discussed, the ultimate goal of this study is to reach a level of 400 responses in both Sweden and Ireland, consequently data collection is still underway.

Once schools had volunteered to participate, teachers within the schools collected the data. An information sheet including directions to administer the DAET was provided, and responsible teachers communicated regularly with the researchers to ensure parity in data collection for all participants. The first part of the DAET (Appendix: A) was administered initially. Participants were allocated 20 minutes to complete their drawings as an in-class activity using available drawing supplies using the same protocol as Fralick, Kearn, Thompson and Lyons [5]. After the 20 minutes, participants received the second part of the survey and were allocated a further 10 minutes to complete this. In the end all materials were gathered by the administering teacher and collected personally from the schools by the researchers.

Results

The results were analyzed with respect to the participants' gender and country of residence in relation to their stereotypical views of engineers' gender and conception based on the responses to the DAET. The participants interest in becoming an engineer in the future was also analyzed with respect to their gender and country of residence.

Stereotypical gender of engineers

In studies which involve the use of the DAET and where the gender of engineers drawn by participants is examined, it is often reported that the gender of some engineers cannot be determined [2], [5], [6], [35], [39]. Therefore, in this study, participants were asked to clarify the gender of their drawn engineers subsequent to completing their drawing. The gender of drawn engineers were coded as either 'male' or 'female' if there was a single or multiple engineers depicted and the participant stated they were exclusively either of those genders. Gender was coded as 'both' if there were multiple engineers and participants stated there were both male and female engineers in the drawing. Gender was coded as 'either' when there was a single or multiple engineers within a drawing and participants stated it could be either male or female.

Finally, gender was coded as ‘other’ if the participant ascribed a gender other than male or female to the engineer in their drawing. From the Irish sample, drawings coded as other consisted of two ‘gender neutral’ codes and one ‘genderless code’, while in the Swedish sample there were three ‘non-binary’ codes and two engineers coded as being ‘neither male nor female’. A full breakdown of the gender of engineers portrayed in the drawings of the full cohort is provided in Table 1 both in relation to the participants’ country of residence and their gender.

Table 1. Gender of drawn engineers.

	Gender of drawn engineer				
	Male	Female	Other	Both	Either
Irish participants					
Male	125 (91.9)	4 (2.9)	1 (0.7)	3 (2.2)	3 (2.2)
Female	93 (62.4)	50 (33.6)	0 (0.0)	5 (3.4)	1 (0.7)
Other	5 (55.6)	2 (22.2)	1 (11.1)	0 (0.0)	1 (11.1)
Prefer not to say	4 (50.0)	2 (25.0)	1 (12.5)	0 (0.0)	1 (12.5)
Swedish participants					
Male	69 (69.7)	12 (12.1)	2 (2.0)	2 (2.0)	14 (14.1)
Female	46 (46.9)	35 (35.7)	3 (3.1)	4 (4.1)	10 (10.2)
Other	5 (62.5)	1 (12.5)	0 (0.0)	0 (0.0)	2 (25.0)
Prefer not to say	3 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (50.0)

Note: Numbers within parentheses = Within participant gender percentages.

Due to the relatively small number of participants portraying engineers other than exclusively either male or female, they were not considered in subsequent analysis pertaining to the stereotypical gender of engineers. The low frequency of participants from these categories would not have allowed for meaningful inferences to be made based on statistical tests.

A bivariate logistic regression analysis was performed to determine the effects of gender and country of residence on the likelihood that participants would portray a male engineer in their drawings, suggesting a male stereotype of engineers (Table 2). The model was statistically significant, $\chi^2(3) = 71.407$, $p < .000$, explained 22.9% (Nagelkerke R^2) of the variance in the depicted gender of engineers and correctly classified 76.7% of cases.

Table 2. Bivariate logistic regression model of the gender of drawn engineers.

	B	SE	Wald	*df*	*p*	OR	95% CI
Gender	2.821	.537	27.569	1	.000	16.801	5.861 – 48.166
Country	1.693	.597	8.053	1	.005	5.435	1.688 – 17.496
Country × Gender	-1.346	.661	4.144	1	.042	.260	.071 - .951
Constant	-3.442	.508	45.921	1	.000	.032	

Note: Gender reference = Male. Country reference = Ireland. OR = Odds ratio.

Despite the statistically significant interaction between the participants’ country of residence and their gender, considering the descriptive statistics in Table 1 indicates that both male and female participants are more likely to draw male engineers regardless of living in either Ireland or Sweden, and Irish and Swedish participants were more likely to draw male engineers regardless of being male or female. Therefore, main effects were explored between countries for both males and females on the gender of their drawn engineers.

A chi-square test of independence was performed to examine the relation between the gender of drawn engineers and males from Ireland and Sweden. A significant association was found, $\chi^2(1) = 9.700$, $p = .002$, $\Phi = .215$, indicating that Irish males were more likely to depict an engineer as male than Swedish males. A second chi-square test of independence was performed to examine the relation between the gender of drawn engineers and females from Ireland and Sweden. The results were not statistically significant, $\chi^2(1) = 1.493$, $p = .222$, indicating that there is no association between Irish and Swedish females' depictions of gender in their drawings of engineers.

Conceptions of engineers

Conceptions of engineers were based on the coding scheme put forward by Carr and Diefes-Dux [41]. Codes were ascribed based on the participants' drawings and their responses to the question "What is your engineer doing?" to ensure accuracy in the interpretation of the drawings. Descriptive statistics are presented in Table 3.

Table 3. Descriptive statistics for conceptions of engineers.

	Irish participants				Swedish participants			
	Male	Female	Other	PNTS	Male	Female	Other	PNTS
Conception								
Designer	27 (20.6)	27 (19.1)	0 (0.0)	0 (0.0)	45 (46.4)	63 (64.3)	4 (57.1)	2 (33.3)
Technician	16 (12.2)	19 (13.5)	2 (22.2)	0 (0.0)	11 (11.3)	16 (16.3)	1 (14.3)	2 (33.3)
Design/Create single	3 (2.3)	4 (2.8)	0 (0.0)	0 (0.0)	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)
Tradesman	18 (13.7)	12 (8.5)	0 (0.0)	1 (12.5)	3 (3.1)	1 (1.0)	0 (0.0)	1 (16.7)
Mechanic	45 (34.4)	49 (34.8)	5 (55.6)	4 (50.0)	2 (2.1)	1 (1.0)	1 (14.3)	0 (0.0)
Laborer/Builder	16 (12.2)	16 (11.3)	2 (22.2)	2 (25.0)	15 (15.5)	2 (2.0)	1 (14.3)	0 (0.0)
Driver	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)
Object/Engine drawn	1 (0.8)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.0)	1 (1.0)	0 (0.0)	0 (0.0)
Factory/Make quantity	0 (0.0)	3 (2.1)	0 (0.0)	0 (0.0)	0 (0.0)	2 (2.0)	0 (0.0)	0 (0.0)
Other professions	5 (3.8)	5 (3.5)	0 (0.0)	1 (12.5)	13 (13.4)	6 (6.1)	0 (0.0)	1 (16.7)
None	0 (0.0)	6 (4.3)	0 (0.0)	0 (0.0)	5 (5.2)	6 (6.1)	0 (0.0)	0 (0.0)

Note: PNTS = prefer not to say [participant gender category]. Numbers within parentheses = within participant gender percentages.

In similarity to the analysis of engineering gender stereotypes, there were too few participants identifying as genders other than male and female to support generalizing meaningful interpretations from the data. Therefore, a comparison how participants in Ireland and Sweden conceived engineers was only conducted for participants identifying as male and female. An overview of the results is presented in Figure 2.

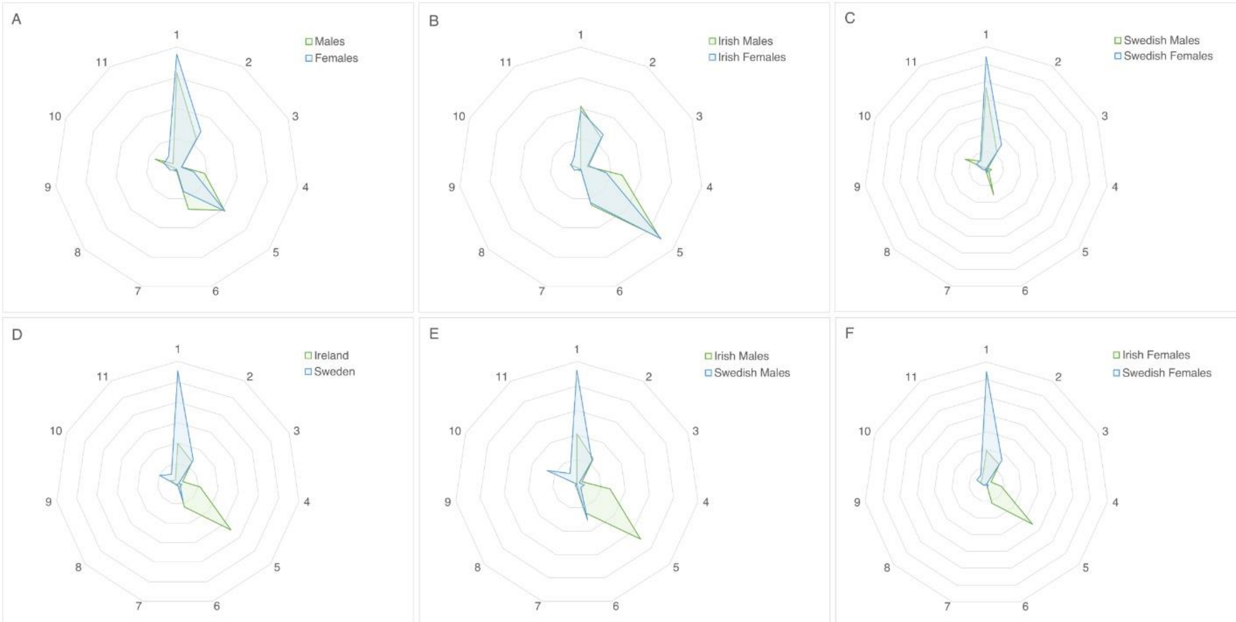

Figure 2. Descriptive analysis of participants' conceptions on engineers. A = Males vs. Females. B = Irish Males vs. Irish Females. C = Swedish Males vs. Swedish Females. D = Ireland vs Sweden. E = Irish Males vs. Swedish Males. F = Irish Females vs. Swedish Females. 1 = Designer. 2 = Technician. 3 = Design/Create single. 4 = Tradesman. 5 = Mechanic. 6 = Laborer/Builder. 7 = Driver. 8 = Object/Engine drawn. 9 = Factory/Make quantity. 10 = Other professions. 11 = None. Chart axis depicts 10% intervals.

The graphs in Figure 2 indicate that while there are differences between how males and females conceive engineers, a large difference can be seen at a country level. Therefore, a series of bivariate logistic regression analyses were performed to determine the effects of gender and the participants' country of residence on the likelihood that they would conceive an engineer as each of the categories proposed by Carr and Diefes-Dux[41]. The only statistically significant models were for the categories of 'designer', $\chi^2(3) = 70.176$, $p < .000$, Nagelkerke $R^2 = .192$, 71.30% cases correctly classified, 'tradesman', $\chi^2(3) = 18.758$, $p < .000$, Nagelkerke $R^2 = .097$, 92.72% cases correctly classified, 'mechanic', $\chi^2(3) = 95.844$, $p < .000$, Nagelkerke $R^2 = .290$, 79.23% cases correctly classified, 'laborer/ builder', $\chi^2(3) = 13.541$, $p < .000$, Nagelkerke $R^2 = .058$, 89.51% cases correctly classified, and 'other professions', $\chi^2(3) = 10.095$, $p < .000$, Nagelkerke $R^2 = .057$, 93.79% cases correctly classified. The results for these models are presented in Table 4.

Table 4. Statistically significant logistic regression models analyzing the relationships between participants' gender and country of residence and their conceptions of engineers.

	B	SE	Wald	*df*	*p*	OR	95% CI
Conception: Designer							
Gender	-.732	.293	6.244	1	.012	.481	.271 – .854
Country	-2.028	.300	45.576	1	.000	.132	.073 – .237
Gender × Country	.824	.422	3.808	1	.051	2.280	.996 – 5.217
Constant	.588	.211	7.774	1	.005	1.800	
Conception: Tradesman							

	B	SE	Wald	*df*	*p*	OR	95% CI
Gender	1.130	1.164	.943	1	.332	3.096	.316 – 30.293
Country	2.200	1.049	4.394	1	.036	9.023	1.154 – 70.579
Gender × Country	-.592	1.229	.232	1	.630	.553	.050 – 6.148
Constant	-4.575	1.005	20.714	1	.000	.010	
Conception: Mechanic							
Gender	.714	1.233	.335	1	.563	2.042	.182 – 22.898
Country	3.945	1.021	14.940	1	.000	51.663	6.99 – 381.857
Gender × Country	-.732	1.259	.338	1	.561	.481	.041 – 5.678
Constant	-4.575	1.005	20.714	1	.000	.010	
Conception: Laborer/Builder							
Gender	2.173	.768	8.010	1	.005	8.780	1.95 – 39.531
Country	1.815	.762	5.674	1	.017	6.144	1.379 – 27.366
Gender × Country	-2.089	.855	5.971	1	.015	.124	.023 – .661
Constant	-3.871	.714	29.361	1	.000	.021	
Conception: Other professions							
Gender	.864	.516	2.804	1	.094	2.373	.863 – 6.525
Country	-.573	.620	.854	1	.356	.564	.167 – 1.902
Gender × Country	-.788	.826	.910	1	.340	.455	.09 – 2.294
Constant	-2.730	.421	41.980	1	.000	.065	

Note: Gender reference = Male. Country reference = Ireland. OR = Odds ratio.

The results of the logistic regressions indicate that Irish fifteen year olds are .132 times less likely to conceive an engineer as a designer[1], 9.023 times more like to conceive an engineer as a tradesman, and 51.663 times more likely to conceive an engineer as a mechanic than Swedish fifteen year olds. The was a significant gender × country of residence interaction effect for the conception of a laborer/builder suggesting a difference between Irish and Swedish fifteen year olds in the difference between males and female's conceptions of an engineer as a laborer/builder. Finally, while the model was significant, there was no significant interaction effect of main effects between participants' gender and country of residence on the participants conceiving an engineer as other professions.

A multinomial logistic regression analysis was performed to determine how likely participants were to conceive an engineer doing one type of activity relative to others (Table 5). The model was statistically significant, $\chi^2(15) = 164.192$, $p < .000$, explained 32.9% (Nagelkerke R^2) of the variance in the participants' conceptions of engineers.

[1] All results in this paper in terms of odds ratios (OR) use males as the gender reference and Ireland as the country of residence reference. To determine the OR for females or Swedish participants, the reciprocal (1/OR) of the given odds ratios can be taken. For example, the result that Irish 15 year olds are .132 times less likely than Swedish 15 year olds to conceive an engineer as a designer indicates that Swedish 15 year olds are 7.576 (1/.132) times more likely than Irish participants to conceive an engineer as a designer.

Table 5. Multinomial regression analyses examining participants' conceptions of engineers relative to each other.

	B	SE	Wald	*df*	*p*	OR	95% CI
Referent: Designer							
Technician							
Intercept	-1.371	0.280	23.967	1	0.000		
Gender	-0.038	0.438	0.008	1	0.930	0.962	0.408 – 2.269
Country	1.019	0.410	6.181	1	0.013	2.771	1.241 – 6.188
Gender × Country	-0.134	0.617	0.047	1	0.829	0.875	0.261 – 2.932
Tradesman							
Intercept	-4.143	1.008	16.897	1	0.000		
Gender	1.435	1.171	1.502	1	0.220	4.200	0.423 – 41.694
Country	3.332	1.066	9.772	1	0.002	28.000	3.466 – 226.201
Gender × Country	-1.030	1.259	0.669	1	0.413	0.357	0.030 – 4.210
Mechanic							
Intercept	-4.143	1.008	16.897	1	0.000		
Gender	1.030	1.240	0.689	1	0.406	2.800	0.246 – 31.829
Country	4.739	1.036	20.925	1	0.000	114.333	15.008 – 871.017
Gender × Country	-1.115	1.286	0.751	1	0.386	0.328	0.026 – 4.082
Laborer/Builder							
Intercept	-3.450	0.718	23.072	1	0.000		
Gender	2.351	0.778	9.142	1	0.002	10.500	2.287 – 48.210
Country	2.927	0.784	13.919	1	0.000	18.667	4.012 – 86.860
Gender × Country	-2.351	0.897	6.878	1	0.009	0.095	0.016 – 0.552
Other professions							
Intercept	-2.351	0.427	30.289	1	0.000		
Gender	1.110	0.531	4.371	1	0.037	3.033	1.072 – 8.584
Country	0.665	0.648	1.054	1	0.305	1.944	0.546 – 6.921
Gender × Country	-1.110	0.869	1.629	1	0.202	0.330	0.060 – 1.812
Referent: Technician							
Tradesman							
Intercept	-2.773	1.031	7.235	1	0.007		
Gender	1.473	1.219	1.460	1	0.227	4.364	0.400 – 47.614
Country	2.313	1.095	4.464	1	0.035	10.105	1.182 – 86.376
Gender × Country	-0.896	1.319	0.461	1	0.497	0.408	0.031 – 5.419
Mechanic							
Intercept	-2.773	1.031	7.235	1	0.007		
Gender	1.068	1.286	0.690	1	0.406	2.909	0.234 – 36.164
Country	3.720	1.066	12.186	1	0.000	41.263	5.111 – 333.133
Gender × Country	-0.981	1.346	0.532	1	0.466	0.375	0.027 – 5.241
Laborer/Builder							
Intercept	-2.079	0.750	7.687	1	0.006		
Gender	2.390	0.849	7.930	1	0.005	10.909	2.068 – 57.557

	B	SE	Wald	*df*	*p*	OR	95% CI
Country	1.908	0.823	5.370	1	0.020	6.737	1.342 – 33.818
Gender × Country	-2.218	0.980	5.122	1	0.024	0.109	0.016 – 0.743
Other professions							
Intercept	-0.981	0.479	4.198	1	0.040		
Gender	1.148	0.630	3.319	1	0.068	3.152	0.917 – 10.835
Country	-0.354	0.694	0.260	1	0.610	0.702	0.180 – 2.735
Gender × Country	-0.976	0.955	1.044	1	0.307	0.377	0.058 – 2.449
Referent: Tradesman							
Mechanic							
Intercept	0.000	1.414	0.000	1	1.000		
Gender	-0.405	1.683	0.058	1	0.810	0.667	0.025 – 18.059
Country	1.407	1.450	0.941	1	0.332	4.083	0.238 – 70.084
Gender × Country	-0.085	1.736	0.002	1	0.961	0.918	0.031 – 27.605
Laborer/Builder							
Intercept	0.693	1.225	0.320	1	0.571		
Gender	0.916	1.378	0.442	1	0.506	2.500	0.168 – 37.260
Country	-0.405	1.283	0.100	1	0.752	0.667	0.054 – 8.240
Gender × Country	-1.322	1.471	0.807	1	0.369	0.267	0.015 – 4.765
Other professions							
Intercept	1.792	1.080	2.752	1	0.097		
Gender	-0.325	1.256	0.067	1	0.796	0.722	0.062 – 8.464
Country	-2.667	1.204	4.906	1	0.027	0.069	0.007 – 0.736
Gender × Country	-0.080	1.455	0.003	1	0.956	0.923	0.053 – 15.973
Referent: Mechanic							
Laborer/Builder							
Intercept	0.693	1.225	0.320	1	0.571		
Gender	1.322	1.438	0.845	1	0.358	3.750	0.224 – 62.764
Country	-1.812	1.258	2.075	1	0.150	0.163	0.014 – 1.922
Gender × Country	-1.237	1.495	0.684	1	0.408	0.290	0.016 – 5.436
Other professions							
Intercept	1.792	1.080	2.752	1	0.097		
Gender	0.080	1.320	0.004	1	0.952	1.083	0.081 – 14.412
Country	-4.074	1.178	11.967	1	0.001	0.017	0.002 – 0.171
Gender × Country	0.005	1.479	0.000	1	0.997	1.005	0.055 – 18.230
Referent: Laborer/Builder							
Other professions							
Intercept	1.099	0.816	1.810	1	0.178		
Gender	-1.242	0.900	1.903	1	0.168	0.289	0.049 – 1.686
Country	-2.262	0.964	5.506	1	0.019	0.104	0.016 – 0.689
Gender × Country	1.242	1.156	1.155	1	0.283	3.462	0.359 – 33.332

Note: Gender reference = Male. Country reference = Ireland. OR = Odds ratio.

The results indicate that in comparison to a designer, Irish participants were 2.771 times more likely than Swedish participants to conceive an engineer as a technician, 28.000 times more likely to conceive an engineer as a tradesman, and 114.333 times more likely to conceive an engineer as a mechanic. In relation to a technician, Irish participants were 10.105 times more likely than Swedish participants to conceive an engineer as a tradesman and 41.263 more likely to conceive an engineer as a mechanic. Finally, in terms of main effects from participants' country of residence, Irish participants were .069 times less likely to conceive an engineer as from other professions than a tradesman, .017 times less likely than to conceive an engineer as from other professions than a mechanic, and .104 times less likely to conceive an engineer as from other professions than a laborer/builder. Additionally, there were two main effects based on gender with males being 3.033 times more likely to conceive an engineer as another profession than a designer and 3.152 times more likely to conceive an engineer as another profession than a technician. Finally, there were two significant gender × country of residence interaction effects whereby there was a significant difference in how 15 year olds participants conceived engineers as a laborer/builder relative to a designer, and as a laborer/builder relative to a technician.

Interest in engineering

In addressing the final research question relative to participants' interest in engineering, a series of ordinal regressions were performed to investigate the potential relationships between their gender, country of residence and how they stereotypically conceived engineers, and their interest in becoming an engineer. A model containing the three-way interaction, all two-way interactions and the main effects of these three variables was explored initially. It was found to be statistically significant, $\chi^2(23) = 110.762$, $p < .000$ with a non-significant goodness-of-fit test, $\chi^2(92) = 89.093$, $p = .566$ suggesting the model and data fit each other well and the assumption of proportional odds was held $\chi^2(92) = 71.155$, $p = .947$. No statistically significant interaction effect or main effect was observed in this model.

A second model containing only an interaction effect between participants' gender and their conception of an engineer, and the main effects of these variables was investigated in terms of predicting the participants interest in engineering. It was found to be statistically significant, $\chi^2(11) = 94.112$, $p < .000$ with a non-significant goodness-of-fit test, $\chi^2(44) = 41.961$, $p = .559$ suggesting the model and data fit each other well and the assumption of proportional odds was held $\chi^2(44) = 15.442$, $p = 1.000$. A statistically significant interaction effect was observed between participants' gender and conceiving engineers as mechanics, Wald $\chi^2(1) = 4.386$, $p < .05$.

A third model containing only an interaction effect between participants' country of residence and their conception of an engineer, and the main effects of these variables was investigated in terms of predicting the participants interest in engineering. The model was not statistically significant, $\chi^2(11) = 19.164$, $p = .058$ and violated the assumption of proportional odds $\chi^2(44) = 118.066$, $p < .000$.

A final model containing only an interaction effect between participants' gender and their country of residence, and the main effects of these variables was investigated in terms of predicting the participants interest in engineering. It was found to be statistically significant, $\chi^2(3) = 86.887$, $p < .000$ with a non-significant goodness-of-fit test, $\chi^2(12) = 18.651$, $p = .097$ suggesting the model and data fit each other well and the assumption of proportional odds was held $\chi^2(12) = 18.808$, $p = .093$. A statistically significant interaction effect was observed between participants' gender and their country of residence, Wald $\chi^2(1) = 5.047$, $p < .05$.

Discussion

Considering the variances in female representation in higher education engineering between Ireland and Sweden, this study provides significant new insight into how 15-year-old students conceive engineers. To date, while the DAET has been used in a pre/post-test fashion [41] it is yet to be used to compare cultural contexts. The interaction effect is particularly interesting as it indicates that, even though males in both countries were more likely to stereotype an engineer as a male, Irish males were significantly more likely to conceive engineers as males than Swedish males. Considering this in conjunction with the level of female representation in higher level engineering education in both countries, this may imply that the traditional stereotype of engineering as a male orientated career is stronger in Ireland than it is in Sweden.

This alone, however, is difficult to interpret, as it is arguably not engineering as a profession that is of importance to this discussion, but rather the beliefs that the participants hold regarding engineers and engineering that are important. It is clear that within both countries, males and females share similar conceptions of engineers and engineering, but there are significant between country differences. In Ireland, fifteen year olds are significantly more likely to conceive engineers as mechanics and tradesmen, whereas in Sweden pupils in the same age group are significantly more likely to engineers to be designers. Therefore, it appears that the gender stereotypes are more appropriately interpreted as Irish males are more likely than Irish females to conceive the activities of mechanics and tradesmen as male orientated activities, while Swedish males are more likely than Swedish females to conceive engineering as design as a more male orientated activity. However, there is a significant difference in the degree to which this stereotype manifests itself between males and females in Ireland and Sweden.

This same complexity is consequently mirrored in the participants' levels of interest in engineering. It is not their level of interest in engineering, but rather their level of interest in engineering as they believe it to be. The results of the ordinal regression models indicate that levels of interest in engineering are predictable by gender × country of residence and gender × conception interactions.

These results have significant implications for higher level engineering education, both in terms of students' decision making about entering an engineering related career, and in sustaining their studies within an engineering program. The fact that there are such clear inter-country differences shows that students in both countries are operating and making decisions with incomplete information. As a result, they may disregard entering engineering based on these misconceptions and never enter a career path which could be of interest to them in practice. Similarly, students could enter an engineer program under a misconception and find out at that stage that their understanding was misaligned with the reality they experience. Such misinformation could be a partial reason for the significant drop-out rates experienced in engineering degree programs [43], and suggests that while future work does need to acknowledge the raw data, i.e. the numbers of students entering programs and their levels of interest, attempts to address such data need to acknowledge the complexity of conceptions of engineering. One recommendation which can therefore be made is that the meaning of 'engineering' needs to be explored early in education to break down stereotypes and allow students to make decisions based on more complete information. Similarly, in terms of research exploring interests in engineering or motivation to study engineering, there is a methodological need to consider participants working definitions of the terms 'engineer' and 'engineering' to allow for more meaningful interpretations to be made from data. Of course it is still valid and useful to examine relative differences in levels of interest and motivation, but greater insight can be gained through the additional recognition that the participants may not be describing their levels of interest or motivation for the same perceived construct.

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Appendix A: Draw an Engineer Test with accompanying survey

Part 1 – 20 Minutes

In the space below, draw an engineer doing engineering work

About the engineer in your drawing:

Is your engineer male or female? ____

What age is your engineer? ____

Where is your engineer working? ____

What is your engineer doing? ____
____
____
____
____
____

About engineering in general:

What do engineers do? ____
____
____
____
____
____

Please tick <u>one</u> option:

How interested are you in being an engineer?

1) Not at all interested ☐
2) Slightly interested ☐
3) Moderately interested ☐
4) Quite interested ☐
5) Very interested ☐

About you:

Age: _______________________

Gender: Male ☐ Female ☐ Other ☐ _____________ Prefer not to say ☐

What would you like to work as after school? _____________________________________

About your mother/female guardian:

What is your mother/female guardians main job (if she does not work now, what was her last job)? ________________

What does/did she do in her job? ____
____

About your father/male guardian:

What is your father/male guardians main job (if he does not work now, what was his last job)? __________________

What does/did he do in his job? ____
____

About your school:

In the below subjects that you study, is your teacher male or female?[2]

Subject	Teachers gender	
1) English …………………………………………	Male □	Female □
2) Irish/Gaeilge …………………………………	Male □	Female □
3) Mathematics …………………………………	Male □	Female □
4) Science ………………………………………	Male □	Female □
5) Business Studies …………………………..	Male □	Female □
6) Art, Craft & Design ………………………..	Male □	Female □
7) Home Economics ………………………….	Male □	Female □
8) Music …………………………………………	Male □	Female □
9) History ………………………………………..	Male □	Female □
10) Geography ………………………………..	Male □	Female □
11) Materials Technology Wood ………..	Male □	Female □
12) Metalwork …………………………………	Male □	Female □
13) Technology ………………………………..	Male □	Female □
14) Technical Graphics ………………………	Male □	Female □
15) Religious Education ……………………	Male □	Female □
16) French ……………………………………….	Male □	Female □
17) German ……………………………………..	Male □	Female □
18) Spanish …………………………………….	Male □	Female □
19) Italian ……………………………………….	Male □	Female □
20) Jewish Studies ……………………………	Male □	Female □
21) Classics ……………………………………..	Male □	Female □

[2] This list represents subjects in Ireland only. The Swedish version contained a different list of subjects.