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The impact of country of schooling and gender on secondary school students' conceptions of and interest in becoming an engineer in Ireland, Kenya and Sweden

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Abstract

Background Given the disparities in gender representation, efforts are needed to make engineering education more inclusive and attractive to young people. It is important that those entering engineering education are making this decision with sufficient understanding of what it means to be an engineer. This study explored how lower secondary education students from Ireland ($n=435$), Kenya ($n=436$), and Sweden ($n=361$) stereotyped engineers, and their interest in becoming an engineer was examined. The Draw an Engineer Test was used to achieve this, and ordinal and logistic regression analyses were conducted to compare the effects of students' genders and country of schooling on the genders and concepts of their drawn engineers, and on their interest in becoming an engineer in the future.

Results A Sankey diagram illustrated significant complexity in the interaction between conceptions of engineering work and fields of engineering. Chi-square tests of association were used to examine the association between students depicting an engineer as either the same or a different gender to themselves and their interest in becoming an engineer. The results of these and the regression analyses indicate that young people's gender explains more variance in the gender of drawn engineers and the country they are studying in explains more variance in their conception of engineers. However, most variance was explained when both students' gender and country of study were considered together. Further, particularly for young females, drawing a female engineer as opposed to a male engineer was positively associated with increased interest in becoming an engineer.

Conclusions There is a need to develop a greater understanding of engineering in young people to ensure they have sufficient information to make decisions regarding related educational pursuits. National-level attempts are needed to present accurate depictions of engineering, and effort needs to be invested in ensuring that young females can identify as engineers. Higher educational access needs to be considered in future work examining future career interests.

Keywords Engineering, Stereotype, Conceptions, Interest

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Introduction

While there is variance across fields, women are typically underrepresented in engineering education in Western countries (Berge et al., 2019; Moloney & Ahern, 2022; Peixoto et al., 2018; Yoder, 2017). A lack of diversity, both in engineering education and then subsequently in the workforce, can impede disciplinary innovation and have negative financial and intellectual implications (Charlesworth & Banaji, 2019; Dezsö & Ross, 2012; Galinsky et al., 2015; Loyd et al., 2013). It can also be indicative of implicit barriers to engineering education faced by women, and much research supports this perspective (Cadaret et al., 2017; Fouad et al., 2016; Howe-Walsh & Turnbull, 2016; Mozahem et al., 2019; Peña-Calvo et al., 2016). The under-representation of women in engineering education is a significant problem for the field, and while a number of explanatory factors have been investigated (cf. Wang & Degol, 2017), societal perceptions of engineering and engineers appears a central tenet (Carberry & Baker, 2018).

The relationship between a person's self-concept and their belief about a field is related to their interest and subsequent engagement in that field (Guo et al., 2017; Murphy et al., 2019). This is particularly important for engineering as it is an ambiguous discipline making it relatively susceptible to stereotypical ascriptions (Buckley et al., 2021; Holbrook et al., 2009). This relationship underscores the importance of understanding how underrepresented groups stereotype a field, and particularly which factors contribute to the manifestation of such stereotypes. Given the evidence that gender- and STEM-related stereotypes can vary across countries (Breda et al., 2020; Moè et al., 2021; Nosek et al., 2009), the central thesis underpinning this work is that cultural differences, specifically those linked to differences between educational systems, are likely to effect young peoples' stereotypes of engineers. Further, it is believed that understanding these stereotypes, their sources, and their influence on young peoples' interest in becoming an engineer will aid other efforts in addressing the problems within engineering education associated with female under-representation. Unfortunately, as previously noted by Capobianco et al. (2011), there is currently a paucity of large-scale data pertaining to conceptions of engineers, particularly in terms of the impact of cultural diversity on such conceptions, which limits the current insight available and thus there is a notable knowledge gap in this regard. Hence, building on evidence indicating that engagement with STEM-related subjects or courses at secondary level education is positively associated with subsequent enrolment and interest in pursuing STEM in higher education (Chachashvili-Bolotin et al., 2016; Jacob et al., 2020; Wang, 2013), this study aimed to explore this thesis in the context of lower secondary education students. The specific contribution of this work is an increased understanding of how cultural differences, largely associated with education systems, interact with a young persons' gender to effect how they stereotype engineers and then how subsequent interest in pursuing engineering as a future career is impacted.

The Draw an Engineer Test (DAET: Knight & Cunningham, 2004) is a survey instrument which was developed to provide a mechanism to elicit stereotypes of engineers and engineering. Research participants, who are usually students but occasionally educators, are asked to "draw an engineer doing engineering work" in a prescribed period of time (Capobianco et al., 2011, p. 309). By being asked to represent a single engineer, the DAET evokes within participants their prototypical definition or stereotype of an engineer. This activity is then often followed by a series of survey questions (Ergün & Doğukan Balçın, 2018; Thompson & Lyons, 2008). While there is no consistently adopted protocol of survey questions within the literature, the functions of these questions range from clarifying participant drawings to gaining a broader understanding of participants' views of engineers and engineering. Within DAET studies, stereotypes of engineering activity and gender are explored and often interpreted with respect to levels of gender representation within cultural contexts (Capobianco et al., 2011; Carr & Diefes-Dux, 2012; Carreño et al., 2010; Cruz López et al., 2011, 2013; Diefes-Dux & Capobianco, 2011; Ergün & Doğukan Balçın, 2018; Fralick et al., 2009; Karatas et al., 2008, 2011; Miel et al., 2018; Newley et al., 2017; Thompson & Lyons, 2008). Through the use of the DAET instrument, this article reports on the results of a large-scale study ($n = 1232$) which explores stereotypes of engineers held by students (approx. 15 years of age) in Ireland, Sweden and Kenya, with an aim of gaining insight into potential stereotypical differences and their associated sources. This work marks an extension to previous DAET studies in that prior work has typically focused exclusively on individual countries (such as Turkey, Mexico, and the U.S.), whereas through this study between country differences are examined. The analyses, which focus on the students self-reported gender, country of schooling, conceptions of engineers, and their interest in pursuing engineering as a career in the future, are viewed through a sociocultural lens. Coupled with a provided consideration of the students' cultural contexts, this study focuses specifically on understanding the potential sources of variation observed within these variables. Given that for young people to come to an accurate understanding about engineering they need to explicitly learn about it (Hester & Cunningham, 2007), the results of this study can support the development of targeted interventions aiming to provide the nuanced conceptions of engineering and engineers needed to ensure that decision-making with respect to pursuing further study or careers in an engineering field is founded on relevant knowledge. It further contributes to the large-scale data Capobianco et al. (2011) identified as lacking with respect to culturally diverse conceptions of engineering.

The included countries were selected based on differences in their levels of female representation in higher level engineering education, differences in exposure to engineering education at secondary level, and to gain insight into possible differences in engineering stereotypes held by young people between developed and developing countries. Specifically, four research questions are addressed:

1. What relationship, if any, exists between lower secondary education students' self-reported gender and their country of schooling, and held engineer gender stereotypes?
2. What relationship, if any, exists between lower secondary education students' self-reported gender and their country of schooling, and held stereotypes of conceptions of engineers (the nature of engineering work)?
3. What relationship, if any, exists between lower secondary education students' self-reported gender and their country of schooling, and their interest in becoming an engineer in the future?
4. Does the relationship between lower secondary education students' self-reported gender and the gender of engineers they illustrate through the DAET have any predictive validity of their interest in becoming an engineer in the future?

To further frame this research, the following section provides a review of DAET research undertaken to date and elaborates on the core concept engineering stereotypes. Details are provided both on the methodological development of the instrument and on empirical findings. This is succeeded by further details on the three countries included in this study with specific relevance to inclusion criteria and to the educational contexts of the participating students.

Review of research using the DAET

Knight and Cunningham (2004) developed the DAET as an adaption of the Draw a Scientist Test (DAST: Chambers, 1983). Methodologically, the DAET is credited for is its capacity to elicit people's stereotypes of engineers and engineering (Capobianco et al., 2011; Cunningham et al., 2005; Ergün & Doğukan Balçın, 2018; Knight & Cunningham, 2004), a function also attributed to the DAST in terms of peoples stereotypes of scientists (Chambers, 1983; Miller et al., 2018). The validity of the DAST was questioned by Ó Maoldomhnaigh and Ní Mhaoláin (1990) who contended that multiple models of scientists could be held by participants but these instruments only request one. Cunningham et al. (2005) later offered the counter argument that by asking for only one image a stereotype is likely to be evoked, which is the intent of the instrument. Research involving the use of "Draw-a" instruments has extended to other occupations such as science teachers (Thomas et al., 2001) and computer scientists (Hansen et al., 2017), and the DAET specifically has seen an increase in adoption in recent years (Dyehouse et al., 2011; Ergün & Doğukan Balçın, 2018; Hirsch, 2018; Koyunlu Ünlü & Dökme, 2017; Miel et al., 2018; Wei & Hill, 2018). This growth in popularity can be attributed to the assumption that such instruments do indeed offer valid and meaningful insight into stereotypical views. Viewing stereotyping as a categorisation and simplification process of groups of people (Augoustinos & Walker, 1998), the DAET essentially requires participants to represent their prototypical concept of an engineer. In other words, the represented engineer can be viewed as "that instance (if there is one) which displays all the typical properties" (Neisser, 1979, p. 182). It is these typical properties which are of most interest to this study due to their potential implications in effecting who enters and finds engineering to be an inclusive field. For example, if a "typical engineer" is viewed as male this could incorrectly suggest to young women that engineering is not an appropriate field for them to enter. Similarly, if a person has come to associate the work of a mechanic with the term mechanical engineer, this misalignment could result in that person not choosing to enter mechanical engineering based on an incorrect stereotype.

To date, participants in DAET studies have included, for example, high school students (Cruz López et al., 2011), university students (Cruz López et al., 2013) and P-12 teachers (Carreño et al., 2010) in Mexico, primary education students (Ergün & Doğukan Balçın, 2018) and gifted secondary school students in Turkey (Koyunlu Ünlü & Dökme, 2017), and elementary school, (Diefes-Dux & Capobianco, 2011), middle school (Fralick et al., 2009), and gifted students in the US (Oware et al., 2007). The main findings relate to engineering gender stereotypes and engineering activity stereotypes. With respect to gender stereotypes, the majority of drawn engineers are depicted as male. Excluding drawings where gender was not discernible, studies have found that approximately 80–100% of male participants draw male engineers, whereas approximately 50–75% of female participants draw male engineers (Capobianco et al., 2011; Carreño et al., 2010; Ergün & Doğukan Balçın, 2018;

Knight & Cunningham, 2004). Where only the frequency of the genders of drawn engineers but not of participants is reported, approximately 70–90% of drawn engineers are depicted as males (Cruz López et al., 2013; Fralick et al., 2009; Karatas et al., 2011; Koyunlu Ünlü & Dökme, 2017). These results suggest a clear divide between male and female participants' engineer gender stereotypes and do reflect broad gender disparities in engineering (OECD, 2020; UNESCO, 2020; Yoder, 2017). However, it is important to note that most studies to date have either taken a qualitative approach to examining collected DAET data or restricted their quantitative analysis to interpretations of descriptive statistics.

With respect to the activities typically associated with engineers as depicted in DAET drawings, much work has focused on developing appropriate coding schemes. Initial work inductively analysed DAET data in terms of the verbs, e.g., "builds" or "fixes", used by participants (Knight & Cunningham, 2004). Later work focused on associated subjects which were attached to these verbs such as "repair cars", "install wiring", and "drive machines" (Cunningham et al., 2005). The development of the "INSPIRE DAET Coding System" to support more systematic and deductive analyses was perhaps the most significant development in this process. Over a series of studies, Diefes-Dux and colleagues created and validated a coding system which allows for drawings to be coded in terms of the people included, objects, system, environment, disposition, and level of sophistication (Capobianco et al., 2011; Diefes-Dux & Capobianco, 2011; Dyehouse et al., 2011; Weber et al., 2011). 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 (Carr & Diefes-Dux, 2012). 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 includes categories of "Designer", "Technician", "Design/create single", "Tradesman", "Mechanic", "Laborer/builder", "Driver", "Object/engine", "Factor/make quantity", "Other professions", and "Other/none" (Carr & Diefes-Dux, 2012, pp. 3–4).

The current study

As noted, evidence across different countries implies that engagement with STEM subjects or courses at second-level education is positively associated with subsequent enrolment or interest in pursuing STEM fields in higher education (Chachashvili-Bolotin et al., 2016; Jacob et al., 2020; Wang, 2013). Beliefs about a field are also associated with engagement and interest with the field, particularly when they are internalised in comparison to one's self-concept in that area (Guo et al., 2017; Murphy et al., 2019). Across different countries and education systems there are different opportunities available to secondary-level students to engage with STEM subjects and depending on the educational system these opportunities are impacted by decisions made by students at different stages of their education. The aim of this study was to conduct an exploratory analysis of secondary education students' stereotypical conceptions of engineers and engineering with respect to nature of work and gender across different cultural contexts (Ireland, Sweden, and Kenya) at locally relevant time-points. Specifically, these time-points related to the end of lower secondary education. This would be just before the students would make decisions on upper secondary education subjects to enrol in which would bring them to the point when they would make decisions pertaining to matriculation into third level education. While culture has many different interpretations (Eisenhart, 2001) and has been explored from different perspectives within engineering education (Godfrey & Parker, 2010), in this study culture is interpreted as the country of the participants schooling.

Secondary education students from Ireland, Kenya and Sweden participated in this study. An important commonality across each of these countries is that within each of their respective education systems, students typically complete lower secondary education at approximately 15 years of age and would be thinking about the subjects they want to study for upper secondary education around this time. In Ireland this relates to students' 3rd year of secondary education, in Kenya this relates to their 2nd year of secondary education, and in Sweden this relates to their 9th year of compulsory education.

To give context to these time-points, following eight years of primary education, Irish secondary education consists of three years of lower secondary education and either 2 or 3 years of upper secondary education. Students typically begin secondary education at approximately 12 years of age. In their 3rd year they sit a national examination known as the Junior Certificate which marks the end of lower secondary education. At the end of upper secondary education students can sit another national examination, with performance in this being the primary mechanism for matriculation to third level education nationally.

In Kenya, following eight years of primary education, secondary education spans four years. Students enrol in their 1st year at approximately 14 years of age. At the beginning of their 3rd year they choose, with the help of teachers, and commence subjects for their final two years of secondary school which can be taught of as upper secondary school. The selection of and performance in these subjects at the end of students' 4th year is directly associated with higher education access and funding opportunities through government sponsorship.

Finally, in Sweden, students begin a 9-year compulsory education programme known as grundskolan at approximately the age of 7. Based on the age of students, within this programme years 1–6 could be viewed as similar to primary education and years 7–9 could be viewed as similar to lower secondary education. The Swedish compulsory school curriculum prescribes separate but related knowledge requirements for the end of year 3, year 6 and year 9 (Skolverket, 2018). At the end of year 9, students receive grades based on national criteria, which serve as selection criteria for admission to upper secondary education, known as gymnasieskolan. There are a number of programmes which students can choose during their time in gymnasieskolan that could be categorised as preparation for advanced study at third level or vocational, and this selection directly impact further education opportunities (cf. Hartell & Buckley, 2022).

These three countries were selected based on four considerations. First, as just discussed, students are at a similar age across each country when entering upper secondary education. Second, Ireland and Sweden are classified as developed countries and Kenya is classified as a developing country (United Nations, 2020). Kenyan students have different educational opportunities to Irish and Swedish students and the three countries were therefore included in the study to examine whether this cultural difference effected the relationship between their stereotypes of engineers and their interest in becoming an engineer. A third reason related to the exposure to engineering education in the lower secondary level education. Lower secondary school students in Ireland have the option to engage with a subject called Engineering. This subject has a strong emphasis on metal craft. However, for the participating students in this study the subject would have been called Metalwork. The Metalwork subject was reformed in 2018 when the data were collected and was replaced by Engineering, but it was introduced nationally for 1st year students and the students in this study were in their 3rd year. Approximately 11% of students nationally were enrolled in the Metalwork subject at the time of data collection (Irish State Examinations Commission, 2019), so as students were randomly sampled within schools it is reasonable to assume that approximately 11% of the Irish sample had direct experience with this subject. That said, non-enrolled students would still be familiar with the subject and it would therefore likely influence Irish students' stereotypes of an engineer across the entire sample. Further to this, there is a subject called Engineering at upper-secondary level in Ireland which has been in existence since 1983 and which also has a focus on metal craft. This subject involves a project element in which model vehicles are often manufactured. It is likely that a knowledge of this subject would also influence engineering stereotypes in Ireland. In Sweden, there is no subject known Engineering, but there are mandatory subjects of Technology and Crafts (Sloyd). There could be considered to have overlap with engineering but to a lesser extent than the Irish Engineering subject, and the terminology is different. In Kenya, the secondary level curriculum has no subject which is explicitly related to engineering. Having different degrees of exposure to the concept of engineering education at a societal level means that any cultural differences observed through this work can be further explored through this lens, which such differences being considered as a possible source of engineering stereotypes.

A final reason for selection of the three countries related to the representational differences in females studying engineering at higher level between them. Ireland and Sweden have significant differences in higher education female representation in engineering according to OECD statistics relating to 2016, which were the most recent available at the time of data collection (OECD, 2020). Within the OECD countries, Sweden had the highest percentage of females enrolled in higher education "engineering and engineering trades" fields (Bachelors, Masters and Doctoral level with equivalents) with 28.33% representation while Ireland was the fifth lowest with 14.13% female representation. The more recent 2017 data still show this disparity with female representation at 28.68% in Sweden and 14.83% in Ireland. With respect to female representation in higher education engineering in Kenya, similar OECD data are not available as it was for Ireland and Sweden. However within the OECD data, "engineering and engineering trades" is a subfield of "engineering, manufacturing and construction" fields, and female representation in tertiary education in this category is available up to 2017 for Ireland and Sweden, and UNESCO provides this data for 2016 only for Kenya (UNESCO, 2020). In Ireland, within "engineering, manufacturing and construction" fields at tertiary level, female representation was 17.45% in 2016 and 18.3% in 2017. In Sweden, female representation was 31.37% in 2016 and 31.53% in 2017. In Kenya, female representation was 19.03% in 2016. The "engineering, manufacturing and construction" category contains subcategories relating to "engineering, manufacturing and construction", "engineering and engineering trades", "manufacturing and processing", "architecture and construction" and "interdisciplinary programmes". Therefore, while the exact representation of females in Kenya within engineering and engineering trade fields cannot be deduced, as for example there could be a relatively large proportion of females within architecture and construction, it would appear that female representation in engineering and related fields in tertiary education in Kenya is closer to that of Ireland than Sweden.

Methods

Approach

In order to examine Irish, Kenyan and Swedish students' conceptions of engineers, the DAET instrument was used. The majority of DAET studies are employed with samples from a single country and with a particular demographic of interest, such as students or teachers. These studies tend to examine the data qualitatively to elicit categorical conceptions of engineers and/or report descriptive statistics, frequencies, or percentages. Comparisons are often made between drawings of male and female participants at a descriptive level. For this study, through using the "INSPIRE DAET Coding System" (Capobianco et al., 2011; Diefes-Dux & Capobianco, 2011; Dyehouse et al., 2011; Weber et al., 2011) and subsequent more concise coding system (Carr & Diefes-Dux, 2012) for categorising engineering fields and conceptions of engineers, logistic and ordinal regression analyses, as well as chi-squared tests of association were used to analyse the data. This approach enabled an extension to previous work by being deductive in the coding of drawn engineers, examining within and between country differences, and analysing data in terms of statistical likelihood as opposed to reporting on descriptive statistics alone. Participating students' self-reported gender, country of schooling, and the relationship between their own self-reported gender and that of their drawn engineers (i.e., these were either the same or different genders) were used as independent variables, with the gender of drawn engineers, the conception of drawn engineers, and students' self-reported interest in becoming an engineer used as dependent variables in respective analyses.

Participants

A total of 1232 students completed the draw an engineer test of which 435 were from Ireland ($M_{age} = 14.66$, $SD_{age} = 0.52$), 436 were from Kenya ($M_{age} = 15.11$, $SD_{age} = 0.95$), and 361 were from Sweden ($M_{age} = 15.10$, $SD_{age} = 0.41$). A full breakdown of the students' demographic information is provided in Table 1. When reporting their gender, students could select "male", "female", "other" or "prefer not to say", and they had the option to self-report their identifying gender if they wished. While the majority of those who identified as non-binary selected "other" did not further self-identify, one student did provide a specific description of their gender. This detail is not shared here to protect their anonymity as it related to one single person.

Table 1 Descriptive statistics: $N = 1232$, mean age (SD) = 14.95 (0.71)

Country	Student gender	*n*	Mean age (SD)
Ireland	Female	217	14.65 (0.52)
	Male	196	14.67 (0.52)
	Other	11	14.45 (0.52)
	Prefer not to say	11	14.82 (0.60)
Kenya	Female	200	14.86 (0.84)
	Male	236	15.32 (0.98)
	Other	0	–
	Prefer not to say	0	–
Sweden	Female	155	15.07 (0.36)
	Male	178	15.11 (0.43)
	Other	15	15.27 (0.59)
	Prefer not to say	13	15.23 (0.44)

UNESCO statistics (2020) show that in Ireland, 62,549 students enrolled in their 3rd year of general secondary education in 2017, a number which reflects an annual increase of between 1500 and 2000 students (60,905 enrolments in 2016 and 59,967 enrolments in 2015). From this data, it is estimated that approximately 64,000 to 65,000 students enrolled in their 3rd year of general secondary education in the 2018/2019 academic year when the Irish data were collected. Using 65,000 as a population size estimate, based on Cochran's sample size formula for sampling precision (Cochran, 1977) at the 95% confidence level the Irish sample has a ± 4.68% confidence interval.

For Kenya, UNESCO enrolment data are only available for the years 2014–2016, but shows a trend with approximately 894,000 enrolments into grade 2 of general secondary education in 2014, approximately 932,000 in 2015 and approximately 964,000 in 2016. As the Kenyan data were collected in 2019, this trend is suggestive of a total population size of between 1 and 1.1 million. Taking 1.1 million as the more conservative estimate, at the 95% confidence level the Kenyan sample has a ± 4.69% confidence interval. However, it must be noted that the schools were purposefully and not randomly selected.

For Sweden, Skolverket provides national education statistics with data from the academic year 2018/2019, when the data were collected in Sweden, showing a total of 112,731 students completed Year 9 of compulsory school (Skolverket, 2020). The Swedish sample, at the 95% confidence level, has a ± 5.15% confidence interval.

Materials

Similar to Capobianco et al. (2011), the DAET instrument used in this study consisted of an A4 sheet of paper with the instruction "In the space below, draw an engineer doing engineering work" with an empty space (7 in. × 7 in.) provided below this for the activity. This was accompanied by a written survey which was provided to students immediately after completion of the drawings. Aligning with Capobianco et al. (2011), students were asked to provide a written response to the question "What is your engineer doing?" and based on Fralick et al., (2009), questions regarding personal information and work setting were also asked. These included the questions "Is your engineer male or female?", "What age is your engineer?", "Where is your engineer working?", and "What is your engineer doing?". These questions served to clarify what was intended to be depicted in the drawings to reduce error associated with researcher inference as results in some DAET studies have drawn engineers genders classified as ambiguous due to a lack of stereotypical gender features (Capobianco et al., 2011; Cruz López et al., 2013; Karatas et al., 2011; Weber et al., 2011). Providing a space for students to self-report these personal details for their drawn engineers mitigated any biases that could have been introduced through researcher stereotyping and ensure authentic coding of student intentions. A 5-point Likert item was also provided asking students "How interested are you in being an engineer?" on a scale from "1: Not at all interested" to "5: Very interested" and they were asked to provide personal demographic information including their age and self-reported gender. The complete version of the instrument is in the Supplementary Material.

Data collection

Prior to data collection, full ethical approval was granted for the collection of data in Ireland by the primary authors' institution. Ethical approval was not required for data collection in Sweden or Kenya as the instruments were approved and administered locally in participating schools by the students' regular teachers, and no information locally considered sensitive or identifying was mandatorily collected or provided to the researchers. In each country it was the students' regular teachers who administered the DAET. Where a student did not want to engage, they could either complete other schoolwork during that time or complete the DAET but not submit it. Further, students were informed that they did not need to provide responses for all questions and could leave some blank if they wanted to.

Data were collected in Ireland during the 2018/2019 academic year. A letter was sent to a random sample of 20 schools of varying sizes and locations by the researchers inviting them to participate. The letter provided details of the study and what would be expected of participating students as well as a copy of the instrument. Seven schools volunteered to participate, who were then sent consent forms for their students and information on administrating the DAET instrument.

Data were collected in Kenya during the 2019/2020 academic year. Two schools were purposefully selected. In Kenya, there are four categories of public secondary school: national schools, county schools, extra-county schools, and sub-county schools. Primary-level performance, socio-economic status, and geographic location largely govern admittance into different types of secondary school. National schools are reserved for both the highest performing students, but also those who can afford to attend. A decision was made to include students from county schools as these would be the most representative of students in Kenya. County schools could include high-performing primary-level students, particularly those who did not have the financial capacity to attend national school, while national schools are more restrictive. Due to the influence of religious missionaries, the majority of public secondary schools in Kenya are single sex schools. Therefore, one school was included whose students were all male, and one was included whose students were all female. A final decision was made to select schools from the outskirts of Nairobi. Schools within Nairobi would typically only include students who reside in the capital, whereas schools on the outskirts would have students both from Nairobi and more rural areas. After selecting two schools that met these criteria, school management was contacted regarding the study and both schools volunteered to participate.

Data were collected in Sweden during the 2018/2019 academic year. Vetenskapens Hus (English translation: House of Science), a Swedish science educational centre, managed the recruitment of schools. A large number of Swedish teachers and students (80,000 annually: Vetenskapens Hus, 2020) attend educational courses at Vetenskapens Hus and while there teachers were directly informed about the study and asked to consider voluntary participation. A total of six schools agreed to participate whose staff were sent further information on administrating the DAET instrument.

In all countries, teachers within schools administered the instrument to their own students and returned the responses to the researchers. The researchers did communicate directly with teachers regarding the administration of the instrument, usually one designated teacher per school, but the researchers never communicated with or came into direct contact with any participating student. In terms of administration, students were first given 20 min to complete their drawings of engineers using available drawing supplies mirroring the protocol of Fralick et al. (2009). Once these were completed, they then received the second part of the survey and were given a further 10 min to complete this.

Data analysis

All statistical testing was conducted using the IBM SPSS Statistics 26 software, with figures produced in RStudio using R version 4.0.3 (R Core Team, 2020) and the ggplot2 (Wickham, 2016, p. 2) and ggalluvial (Brunson, 2020) packages. Data analysis initially focused on the impact of students' gender and their country of schooling as two nominal dependent variables across the three independent variables of (1) the gender of drawn engineers, (2) students' stereotyped conceptions of engineers based on their drawings, and (3) students' interest in becoming an engineer. A fourth analysis was then conducted by taking a comparison of the students' self-reported gender and the gender of their drawn engineers as a binary (same/different) independent variable with their self-reported interest in becoming an engineer in the future as the dependent variable. The results section is therefore divided into four associated sub-sections. Only students and drawn engineers which were coded as either male or female were included in the analyses due to low frequencies of students identifying as a gender other than male or female and low frequencies of drawn engineers coded as a gender other than male or female.

First, a binary logistic regression was used to examine the likelihood of the gender of drawn engineers being either male or female based on the students' own gender and country of schooling. None of the relevant assumptions of having a dichotomous dependent variable, having one of more independent variables, and having independence of observations were violated.

Following this, the "INSPIRE DAET Coding System" (Capobianco et al., 2011; Diefes-Dux & Capobianco, 2011; Dyehouse et al., 2011; Weber et al., 2011) was used to code the field of engineering depicted in student drawings and the more concise coding system subsequently developed by Carr and Diefes-Dux (2012) was used for coding the depicted conceptions of drawn engineers. Both of these coding schemes are deductive, however as previously noted there is a code for "other professions" in the coding scheme developed by Carr and Diefes-Dux (2012). Drawings for which this code was applied to were further inductively coded to add specificity to these other professions. This inductive process involved labelling the drawings with discrete professions by the coders. The coding process was completed by two of the authors, the first and fourth. Both worked collaboratively, in person, to code all drawings together. Any disagreements that arose were discussed and the codes to be applied were agreed prior to moving on to the next drawing. The data from Ireland were the first dataset to be collected, and the coding process involved both researchers first coding 50 drawings with the intent of familiarising themselves with the instruments. These drawings were then re-coded at the end of the Irish dataset as it was acknowledged that this familiarisation process could have resulted in some inappropriate codes being applied. It was noted at this time that there was little need to recode the drawings when revisited. In general, the coding schemes were straight forward to apply as the drawings could be described as stereotypical of specific occupations and the coding schemes were developed from such drawings in prior studies. However, some Irish and Swedish students depicted more than one engineer despite only being asked to draw one. In the Irish sample, 20 students (4.59%) drew two engineers, and 10 (2.77%) drew two engineers in the Swedish sample. Every Kenyan student drew only one engineer. To account for this, in the dataset each of the drawn engineers were considered individual cases. Therefore, while there were 435 students in the Irish dataset there were 455 cases of drawn engineers, and while there were 361 Swedish students there were 371 cases of drawn engineers.

Prior to examining the impact of the independent variables on the nature of engineering activity depicted, the coded fields of work and conceptions of engineering were compared. A Sankey diagram was created with the intention of gaining a visual overview of how these variables interacted. This indicated that an interaction between engineering fields and conceptions of engineers would be too complex to examine further given the current sample size. Based on the argument of Carr and Diefes-Dux (2012) that the conceptions on engineers was the key question in this area, the analysis proceeded using only this variable. Due to the nominal nature of the independent variables, a multinomial regression analysis was used to examine their impact on conceptions of engineers. Again, none of the relevant assumptions were violated. This analysis allowed for the likelihood of an engineer to be stereotyped a certain way to be estimated based on participating students' gender and country of schooling. Data analysis then focused on students' interest in becoming an engineer. As interest was measured with a Likert scale, a non-parametric Kruskal–Wallis rank sum test and Dunn's tests for post hoc testing was used to compare differences in levels of interest between male and female students across the three countries. This was followed by an ordinal regression analysis to examine the likelihood of showing a higher interest in becoming an engineer, where again no relevant assumption was violated. Finally, Chi-squared tests of associated were used to examine whether there was a relationship between a comparison of the students' self-reported gender and the gender of their drawn engineers with their self-reported interest in becoming an engineer in the future. These tests were conducted with the entire sample, and then across each country included in this study.

Results

Are students' self-reported gender and country of schooling associated with the gender of drawn engineers?

Students were unrestricted in how they described the gender of their drawn engineers, however for the analysis they were coded as either "male", "female", "other" or "either". The "male" code was used for descriptions such as "male" or "a man", the female code was used for descriptions such as "female" or "a woman", and the "either" code was used for instances such as "my engineer could be either a man or a woman" or when only one person was represented in the picture but their gender was described as "both". The "other" code was used for a variety of descriptions outside of the binary male–female categories. In Ireland, two engineers were described as "other", one was described as "genderless", two were described as "gender neutral" and one was described as "non-binary". In Sweden, four engineers were described as "other", seven were described as "non-binary", three were described as "gender neutral", one was described as "transgender male", one was described as "transgender female", and one was described as "transitioning". A full breakdown, using the codes "male", "female", "other" and "either" is presented in Table 2.

A binomial logistic regression was conducted to examine the associations between the depicted gender of engineers, the students' self-reported gender and the country they were studying in. Due to the low frequency of students identifying as a gender other than male or female and due to the low frequency of students who identified their drawn engineer as a gender other than male or female (Table 2), only male and female identifying students who drew a male or female engineer were included in the analysis ($n = 1153$). Males were used as the reference category for the students' gender, and Sweden was used as a reference category for the country the students were from (Table 3). Model 1 was statistically significant, $\chi^2(1) = 197.898$, $p < 0.001$ and explained 23.6% of the variance in the gender of drawn engineers (Nagelkerke $R^2 = 0.236$). It shows a statistically significant main effect of gender such that male students were 9.009 (1/0.111) times more likely than females to draw a male engineer. Model 2, which looked at a possible main effect of the country the students were from, was not statistically significant, $\chi^2(2) = 2.727$, $p = 0.256$. Model 3 was statistically significant, $\chi^2(3) = 205.238$, $p < 0.001$ and explained 24.4% of the variance in the gender of drawn engineers (Nagelkerke $R^2 = 0.244$). It shows a statistically significant effect of gender when controlling for the country that students were studying in such that males were 9.346 (1/0.107) times more likely than females to draw a male engineer. A significant overall effect of the country that students were from is also shown when controlling for gender, Wald $\chi^2(2) = 7.196$, $p < 0.05$, with a significant simple effect that Irish students were 1.526 times more likely than Swedish students to draw a male engineer. A non-significant simple effect was observed that Swedish students were 1.005 (1/0.995) times more likely that Kenyan students to draw a male engineer. From this, it can be determined that, controlling for the students' gender, Irish students were 1.533 (1.526/0.995) times more likely to draw a male engineer than Kenyan students.

Model 4 was statistically significant, $\chi^2(3) = 213.216$, $p < 0.001$ and explained the most variance in the gender of drawn engineers (Nagelkerke $R^2 = 0.252$). Additionally,

Table 2 Gender of drawn engineers

Student country	Student gender	Gender of drawn engineer			
		Male	**Female**	**Other**	**Either**
Ireland	Female	144 (62.88)	82 (35.81)	–	3 (1.31)
	Male	190 (93.60)	9 (4.43)	2 (0.99)	2 (0.99)
	Other	6 (54.55)	2 (18.18)	3 (27.27)	–
	Prefer not to say	7 (63.64)	2 (18.18)	1 (9.09)	1 (9.09)
Kenya	Female	103 (51.50)	96 (48.00)	–	1 (0.50)
	Male	218 (93.97)	14 (6.03)	–	–
	Other	–	–	–	–
	Prefer not to say	–	–	–	–
Sweden	Female	84 (52.83)	57 (35.85)	7 (4.40)	11 (6.92)
	Male	136 (74.32)	20 (10.93)	8 (4.37)	19 (10.38)
	Other	10 (62.50)	2 (12.50)	2 (12.50)	2 (12.50)
	Prefer not to say	4 (28.57)	6 42.86)	–	4 (28.57)

Numbers within parentheses are within student gender percentages

Table 3 Binomial logistic regression with the gender of drawn engineers as the dependent variable

	Model 1			Model 2			Model 3			Model 4		
	W (df)	**B (SE)**	**OR (95% CI)**	**W (df)**	**B (SE)**	**OR (95% CI)**	**W (df)**	**B (SE)**	**AOR (95% CI)**	**W (df)**	**B (SE)**	**AOR (95% CI)**
Constant	256.641 (1)**	2.538 (0.158)	12.651	62.862 (1)**	1.050 (0.132)	2.857	146.348 (1)**	2.423 (0.199)	11.171	64.070 (1)**	1.917 (0.239)	6.800
Gender	148.869 (1)**	− 2.195 (0.180)	0.111 (0.078, 0.158)				151.833 (1)**	− 2.234 (0.181)	0.107 (0.075, 0.153)	26.939 (1)**	− 1.529 (0.295)	0.217 (0.122, 0.386)
Country				2.689 (2)			7.196 (2)*			9.193 (2)*		
Country (Ireland)				1.99 (1)	0.250 (0.178)	1.285 (0.907, 1.819)	4.729 (1)*	0.422 (0.194)	1.526 (1.043, 2.233)	7.388 (1)**	1.133 (0.417)	3.105 (1.372, 7.027)
Country (Kenya)				0.015 (1)	0.021 (0.172)	1.021 (0.728, 1.432)	0.001 (1)	− 0.005 (0.191)	0.995 (0.685, 1.445)	5.147 (1)*	0.829 (0.365)	2.290 (1.119, 4.685)
Country × Gender										8.123 (2)*		
Country (Ireland) × Gender										4.124 (1)*	− 0.958 (0.472)	0.384 (0.152, 0.967)
Country (Kenya) × Gender										7.178 (1)**	− 1.146 (0.428)	0.318 (0.137, 0.735)
χ^2	$\chi^2(1) = 197.893, p < 0.001$			$\chi^2(2) = 2.727, p = 0.256$			$\chi^2(3) = 205.238, p < 0.001$			$\chi^2(5) = 213.216, p < 0.001$		
-2 Log likelihood	1075.840			1271.006			1068.495			1060.518		
Cox and Snell R^2	0.158			0.002			0.163			0.169		
Nagelkerke R^2	0.236			0.004			0.244			0.252		
Hosmer and Lemeshow	$\chi^2(0) = 0$			$\chi^2(1) = 0, p = 1$			$\chi^2(4) = 8.386, p = .078$			$\chi^2(4) = 0, p = 1$		

*$p < 0.05$. **$p < 0.01$. Independent variable = Drawn engineers' gender. W = Wald. df = Degrees of freedom. SE = Standard error. OR = Odds ratio. AOR = Adjusted odds ratio. CI = confidence interval. Gender reference = Male. Country reference = Sweden. Model 3 and Model 4 coefficients are adjusted for all covariates

the significant country × gender interaction effect, Wald $\chi^2(2) = 8.123$, $p < 0.05$, indicates that the differences in likelihood between student genders with respect to drawing a male of female engineer differs across countries, and that the differences in the likelihood between students from different countries with respect to drawing a male of female engineer differs across their genders. The inclusion of the interaction effect in the model effects the interpretation of the coefficients. Each gender effect, in this case there is only one, applies only to the reference country which in this case is Sweden. Therefore, the model identifies that Swedish males were 4.608 (1/0.217) times more likely that Swedish females to draw a male engineer, and that this effect was statistically significant. Relative to this effect, the interaction coefficients describe how much of a difference exists across countries, and therefore can be used to compute the comparative effects in Ireland and Kenya. For example, the country × gender interaction for Ireland is 0.384 times the size of the effect in Sweden, and therefore Irish males were 12 [1/(0.217 × 0.384)] times more likely than Irish females to draw a male engineer. Similarly, Kenyan males were 14.49 [1/(0.217 × 0.318)] times more likely than Kenyan females to draw a male engineer.

The country coefficients also only relate to the reference gender category, which in this case was male. The model indicates that male Irish students were 3.105 times more likely than male Swedish students to draw male engineers, and that male Kenyan students were 2.290 times more likely than male Swedish students to draw male engineers. From this, it can be determined that male Irish students were 1.356 (3.105/2.290) times more likely than male Kenyan students to draw male engineers. Relative to these effects, the interaction coefficients describe how much of a difference exists across genders and can therefore be used to compute the comparative coefficients for females. It can be deduced that Irish females were 1.192 (3.105 × 0.384) times more likely than Swedish females to draw a male engineer, that Swedish females were 1.373 [1/(2.290 × 0.318)] times more like than Kenyan females to draw a male engineer, and that Irish females were 1.637 (1.192/0.728) times more likely than Kenyan females to draw a male engineer.

Finally, the gender × country interaction coefficient between Ireland and Kenya is 0.832, which can be computed through a comparison of the either the previously calculated effect sizes between countries and genders or the interaction terms in the model (0.318/0.382). A clear interaction is visible as male Kenyan students were more likely than male Swedish students to draw a male engineer, but female Kenyan students were less likely than female Swedish students to draw a male engineer. Male Irish students were more likely than both Swedish and Kenyan male students to draw a male engineer and female Irish students were more likely than both Swedish and Kenyan female students to draw a male engineer. This interaction, shown in Fig. 1, indicates that all groups were more likely to draw a male engineer than a female engineer. Further, these results illustrate that while students' gender accounted for more variance in likelihood to draw a male engineer than the country they were from, there is a need to consider both young people's gender and their cultural context with respect to their stereotypical views on engineers' genders.

Are students' self-reported gender and country of schooling associated with their conceptions of engineers?

The next phase of the analysis explored the nature of work that the drawn engineers were depicted as engaging in, relative to the students' country and gender. For this, the drawings were coded along two dimensions; the field of work from the INSPIRE DAET coding scheme (Weber et al., 2011), and the conception of the engineer based on the simpler coding scheme developed by Carr and Diefes-Dux (2012). The full coding scheme is presented in Table 4.

Figure 2 illustrates the relationships between the depicted gender, engineering fields and conceptions of engineers from the students' drawings. It is evident that female students were more likely to draw female engineers as found through the previous binomial logistic regression (Table 3). Observing the width and direction of the bands reveals that within countries, there is a similarity between the student genders in how engineering fields relate to the conceptions of engineers, but this relationship differs between countries. Based on the similarities within countries across genders and differences between countries, in order to reduce a dimension for the subsequent analysis, only the conceptions of engineers are considered when describing the nature of work drawn engineers were engaging with. To gain a clearer understanding of this data, the raw data for each panel are described in the additional files, which are available at: https://osf.io/dkqyn/.

A multinomial logistic regression analysis was conducted to explore the likelihood of a student drawing an engineer engaging with a particular type of work. However, many of the codes for describing the conceptions of engineers were only used within one country, such as the "archaeologist" code which was only used by Irish students, or had too low a frequency for any meaningful analysis (Fig. 3). Therefore, the analysis only included the data pertaining to drawings with engineers coded as a "Designer", "Laborer", "Mechanic", "Scientist", "Site manager", "Technician" or "Tradesman". Each of these except

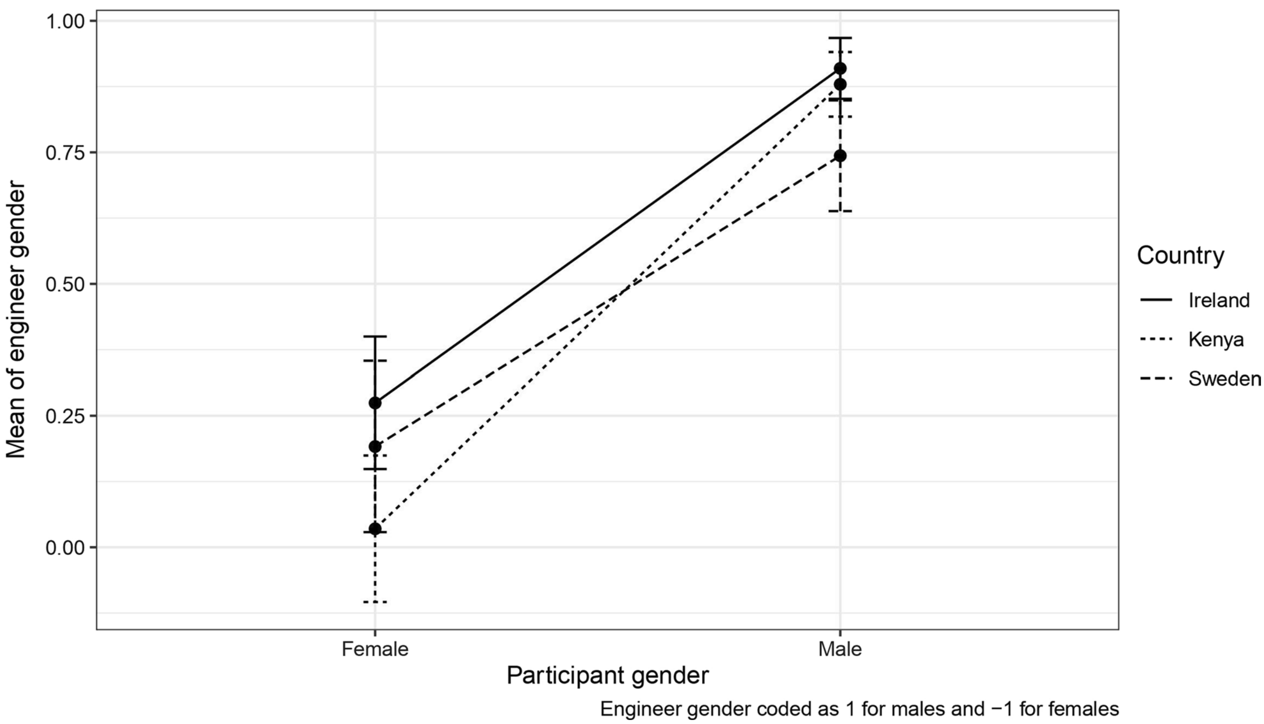

Fig. 1 Interaction between students' gender and the country they were studying in and the probability that they would draw a male engineer. Coefficients greater than 0 indicate a higher probability of drawing a male engineer. If a coefficient was negative, it would have indicated an increased probability of drawing a female engineer

for the "Scientist" code was used in each country by both male and female students. The "Scientist" code was not used for any of the drawings from Irish students.

The analysis again only included students who identified as either male or female ($n = 1074$). Using the conceptions of engineers as the dependent variable, a model was examined which included main effects of students' country and gender and a gender × country interaction effect as independent variables. Only one interaction effect, between Sweden and Kenya relating to the likelihood of drawing a labourer compared to a designer was significant $\chi^2(1) = 4.895$, $p = 0.027$. As no other interaction effects were significant, the interaction term was excluded from the analysis. The results are presented in Table 5 where the "Designer" conception is used as the reference category. While coefficients from other conceptions can be determined from this, as was demonstrated previously with regard to Table 3, this would be laborious. Therefore, Additional file 7: Table S7 (available at: https://osf.io/dkqyn/) provides coefficients for each conception as the reference category.

Model 1 was statistically significant, $\chi^2(6) = 17.807$, $p = 0.007$ and shows that, without controlling for the country students were from, the students' gender explained 1.7% of the variance in the likelihood of representing an engineer as different conceptions. Model 2 was statistically significant, $\chi^2(12) = 482.276$, $p < 0.001$ and shows that, without controlling for the students' gender, the country that students were from explained 37.3% of the variance in the likelihood of representing an engineer as different conceptions.

Model 3 includes both gender and country as independent variables and describes adjusted odds ratios, i.e., gender coefficients are adjusted for the effect of the country students were from and country coefficients are adjusted for the effect of student' gender (Table 5). By doing this, it is more reflective of real-world scenarios as these two variables do naturally interact. This model was statistically significant $\chi^2(18) = 503.972$, $p < 0.001$ and explained 38.6% of the variance in the likelihood of representing an engineer as different conceptions. Similar to the bivariate logistic regression which explored the likelihood of drawing a male or female engineer, the results of this analysis indicate the necessity of considering both a young person's gender and the country they are from with respect to their understanding of engineers and engineering. However, unlike the bivariate regression which showed that the students' gender had a greater effect on the gender of drawn engineers, the country the students were from had a greater effect on their conception of an engineer. Additional file 7: Table S7 provides the full results of the analysis.

Table 4 Coding scheme used to describe the nature of work of drawn engineers

Field of work codes	Conception of engineer codes
Not mentioned	Designer
Aeronautics and Astronautics	Design/Create single
Agricultural and Biological	Driver
Civil	Factory/Make quantity
Chemical	Laborer/Builder
Computer	Mechanic
Construction	Object/Engine
Electrical	Technician
Environmental	Tradesman
Industrial	Other/None
Land Surveying and Geomatics	Other professions*
Materials	Archaeologist
Mechanical	Businessman
Educational	Doctor
Policy	Fast food server
Blank	Fireman
	Mathematician
	Politician
	Researcher
	Salesperson
	Scientist
	Site manager
	Student
	Teacher

Note: *For this study, the "Other professions" code within the "conceptions of engineer codes" was not used in the analysis. Instead, drawings which this code was applied to were further inductively coded. This process revealed 13 specific professions, listed below the "Other professions" code in the table. These were used in the analysis

Are students' self-reported gender and country of schooling associated with their interest in becoming an engineer?

The next analysis examined students' interest in becoming an engineer, again with respect to their gender (male and female only) and the country they were from ($n = 1178$). Figure 4 illustrates the percentage of students who gave each response based on their gender and the country they were from. Visually, the Kenyan sample appears quite different to the Irish and Swedish samples both in that Kenyan males and females have a similar answer profile to each other where the Irish and Swedish samples have visually different answer profiles between genders, and in Kenya there appears a higher tendency to be more interested in becoming an engineer. Further, Irish and Swedish males appear to have a similar response profile as do Irish and Swedish females.

A Kruskal–Wallis rank sum test was conducted to statistically examine these differences in ranked interest in becoming an engineer between the six groups and a statistically significant result was observed, $\chi^2(5) = 308.048$, $p < 0.001$. Post hoc pairwise comparisons were computed using Dunn's test with a Bonferroni adjusted alpha value. The results (Table 6) indicate significant differences between all groups except for between Kenyan males and females, Irish and Swedish males, and Irish and Swedish females.

Finally, in order to examine the likelihood of showing a higher interest in becoming an engineer, an ordinal regression analysis was conducted with interest in becoming an engineer as the dependent variable and the students' country and gender as independent variables ($n = 1178$). Similar to with the multinomial regression, an initial model examined a potential gender × country interaction. There was no statistically significant interaction effect so this was excluded from the analysis. The results (Table 7) provide three statistically significant models. Model 1 was statistically significant, $\chi^2(1) = 16.389$, $p < 0.001$, and explained 1.4% of the variance in students' interest in becoming an engineer. It indicated a statistically significant main effect of gender in that males were 1.522 (1/0.657) times more likely than females to be more interested in becoming an engineer. Model 2 was statistically significant, $\chi^2(2) = 132.256$, $p < 0.001$, and explained 11.1% of the variance in students' interest in becoming an engineer. It indicated statistically significant simple effects relating to the country students were from in that Kenyan students were 3.718 times more likely than Swedish students and 3.802 (1/0.263) times more likely than Irish students to be more interested in becoming an engineer. There was no significant difference between Irish and Swedish students. Model 3, which presents adjusted odds ratios, was statistically significant, $\chi^2(3) = 144.268$, $p < 0.001$, and explained 12% of the variance in students' interest in becoming an engineer. Controlling for the country students were from, males were 1.439 (1/0.695) times more likely than females to be interested in becoming an engineer. Controlling for students' gender, Kenyan students were 3.677 times more likely than Swedish students and 3.69 (1/0.271) times more likely than Irish students to be more interested in becoming an engineer. These results indicate that both students' gender and the country they were from significantly influenced their interest in becoming an engineer, however the effect of the country they were from contributed more to the explained variance than the effect of their gender.

Is a comparison between student' self-reported gender and the gender of their drawn engineers associated with their interest in becoming an engineer?

A total of 12 Chi-square tests of association were conducted to examine the relationship between the students' interest in becoming an engineer and whether they drew

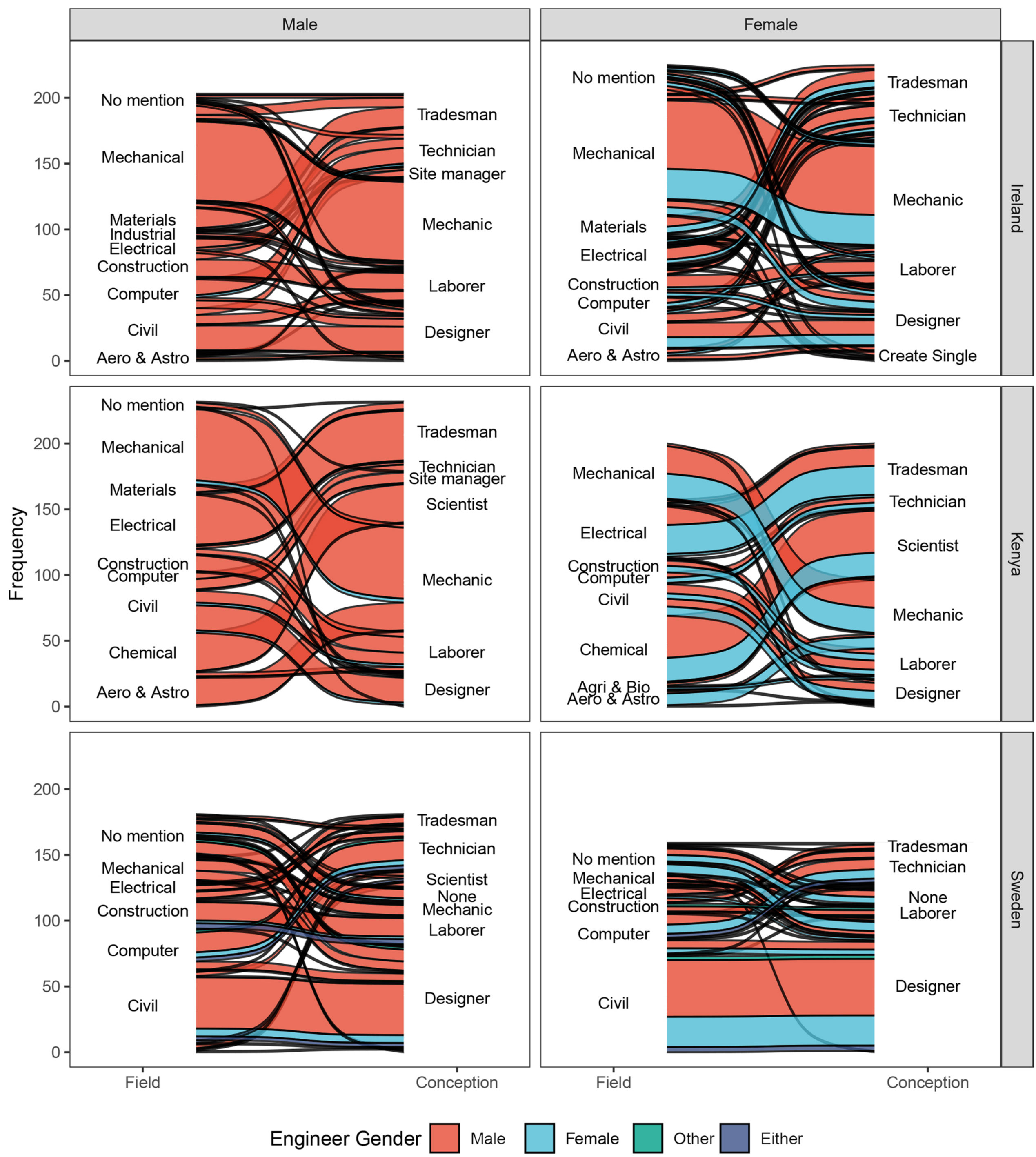

Fig. 2 Sankey diagrams depicting the associations made by male and female Irish, Kenyan, and Swedish students between genders of drawn engineers, fields of engineering and conceptions of engineering work. Engineering fields and conceptions are not labelled if there are fewer than 5 instances. Y axes illustrate raw frequencies. The raw data for each panel are described in Additional file 1: Table S1, Additional file 2: Table S2, Additional file 3: Table S3, Additional file 4: Table S4, Additional file 5: Table S5, Additional file 6: Table S6, available at: https://osf.io/dkqyn/

an engineer that they identified as the same of a different gender to their own self-reported gender (Fig. 5). This was exploratory and to control the family-wise error rate a Bonferroni adjusted alpha value of $\alpha_{adj} = 0.0042$ (0.05/12) was used as a threshold for statistical significance. As before, due to relatively few students identifying as a gender other than male or female and drawing an engineer with an identified gender as other than male or female,

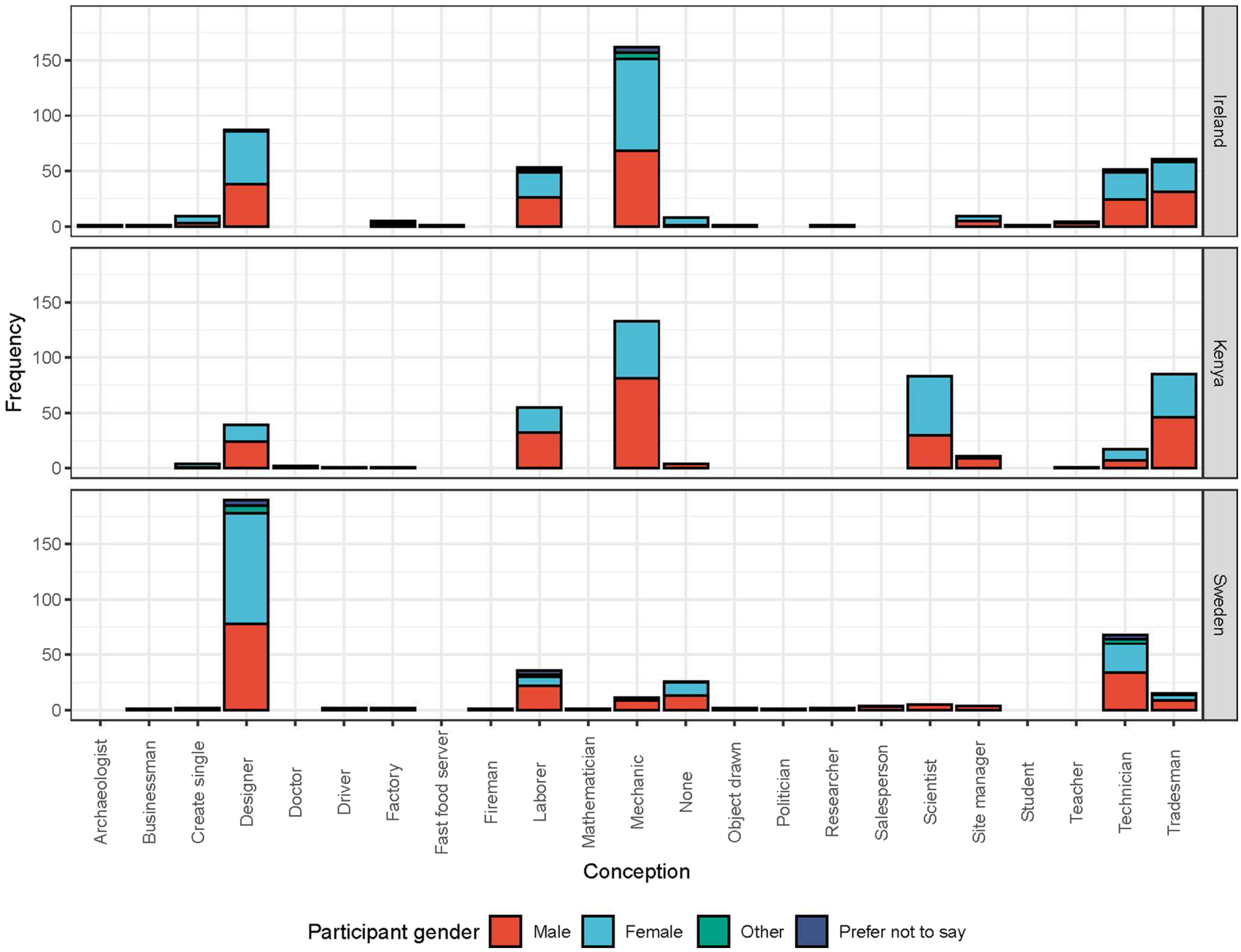

Fig. 3 Frequency of conceptions of engineers based on students' drawings across their country and gender

only students who identified as male or female and who drew male or female engineers were included. First, this association was examined with the entire dataset and a statistically significant association was observed, $\chi^2(4, n=1147)=70.056$, $p<0.001$, $\eta=0.229$, suggesting that in general there is an association between held engineer gender stereotypes and how they relate to a students' own gender across the included demographics, and interest in becoming an engineer in the future. To gain a more nuanced understanding of this association, it was then explored within male and female students and across each included country. In male students only a significant effect was not observed, $\chi^2(4, n=584)=2.809$, $p=0.590$, $\eta=0.042$, whereas in female students a significant effect was observed, $\chi^2(4, n=563)=25.666$, $p<0.001$, $\eta=0.200$. A significant effect was observed within the Irish students, $\chi^2(4, n=424)=51.394$, $p<0.001$, $\eta=0.332$, and Swedish students, $\chi^2(4, n=292)=19.165$, $p<0.001$, $\eta=0.227$, however one was not observed within Kenyan students, $\chi^2(4, n=431)=8.525$, $p=0.074$, $\eta=0.106$. Finally, the association was examined within both males and females across each included country, however no statistically significant effects were observed [Irish males, $\chi^2(4, n=198)=0.717$, $p=0.949$, $\eta=0.026$; Irish females, $\chi^2(4, n=226)=12.890$, $p=0.012$, $\eta=0.190$; Kenyan males, $\chi^2(4, n=232)=3.599$, $p=0.463$, $\eta=0.019$; Kenyan females, $\chi^2(4, n=199)=9.933$, $p=0.042$, $\eta=0.187$; Swedish males, $\chi^2(4, n=154)=2.213$, $p=0.697$, $\eta=0.058$; Swedish females, $\chi^2(4, n=138)=7.872$, $p=0.096$, $\eta=0.136$].

Discussion

Summary of results

The exploratory analysis regarding the depicted gender of drawn engineers revealed that all groups were more likely to draw a male engineer than a female engineer, and across each country male students were more likely than female students to draw a male engineer. This is, in general, consistent with prior DAET studies (Capobianco et al., 2011; Carreño et al., 2010; Cruz López et al.,

Table 5 Multinomial logistic regression with the conception of drawn engineers as the dependent variable

	Model 1			Model 2			Model 3		
	W (df)	**B (SE)**	**OR (95% CI)**	**W (df)**	**B (SE)**	**OR (95% CI)**	**W (df)**	**B (SE)**	**AOR (95% CI)**
Reference: Designer									
Conception: Laborer									
Intercept	16.343 (1)**	− 0.586 (0.145)		77.835 (1)**	− 1.964 (0.223)		51.021 (1)**	− 1.721 (0.241)	
Gender	5.335 (1)**	− 0.499 (0.216)	0.607 (0.397, 0.927)				5.885 (1)*	− 0.554 (0.229)	0.574 (0.367, 0.899)
Country (Ireland), Ref = Sweden				24.810 (1)**	1.425 (0.286)	4.159 (2.374, 7.288)	26.259 (1)**	1.478 (0.288)	4.386 (2.492, 7.720)
Country (Kenya), Ref = Sweden				55.936 (1)**	2.29 (.306)	9.873 (5.418, 17.991)	55.800 (1)**	2.296 (0.307)	9.937 (5.440, 18.151)
Country (Ireland), Ref = Kenya				9.771 (1)**	− 0.864 (0.277)	0.421 (0.245, 0.724)	8.665 (1)**	− 0.818 (0.278)	0.441 (0.256, 0.761)
Conception: Mechanic									
Intercept	1.396 (1)	0.140 (0.119)		69.589 (1)**	− 3.020 (0.362)		58.544 (1)**	− 2.844 (0.372)	
Gender	2.783 (1)	− 0.279 (0.167)	− 0.756 (0.545, 1.050)				3.924 (1)*	− 0.383 (0.193)	0.682 (0.467, 0.996)
Country (Ireland), Ref = Sweden				85.907 (1)**	3.587 (.387)	36.119 (16.917, 77.115)	87.148 (1)**	3.624 (0.388)	37.471 (17.510, 80.186)
Country (Kenya), Ref = Sweden				108.962 (1)**	4.232 (0.405)	68.859 (31.107, 152.427)	108.936 (1)**	4.237 (0.406)	69.170 (31.218, 153.260)
Country (Ireland), Ref = Kenya				8.016 (1)**	− 0.645 (0.228)	0.525 (0.336, 0.820)	7.175 (1)**	− 0.613 (0.229)	0.542 (0.346, 0.848)
Conception: Scientist									
Intercept	51.367 (1)**	− 1.394 (0.194)		47.167 (1)**	− 4.001 (0.583)		48.202 (1)**	− 4.212 (0.607)	
Gender	1.494 (1)	0.308 (0.252)	1.361 (0.830, 2.230)				1.780 (1)	0.380 (0.285)	1.463 (0.837, 2.558)
Country (Ireland), Ref = Sweden				N/A	N/A	N/A	N/A	N/A	N/A
Country (Kenya), Ref = Sweden				59.664 (1)**	4.744 (0.614)	114.940 (34.486, 383.087)	59.507 (1)**	4.740 (0.614)	114.431 (34.318, 381.569)
Country (Ireland), Ref = Kenya				N/A	N/A	N/A	N/A	N/A	N/A
Conception: Site Manager									
Intercept	63.416 (1)**	− 2.000 (.251)		53.849 (1)**	− 3.714 (0.506)		39.123 (1)**	− 3.253 (0.520)	
Gender	6.564 (1)*	− 1.245 (0.486)	0.288 (0.111, 0.746)				6.956 (1)**	− 1.301 (0.493)	0.272 (0.104, 0.716)

Table 5 (continued)

	Model 1			Model 2			Model 3		
	W (df)	**B (SE)**	**OR (95% CI)**	**W (df)**	**B (SE)**	**OR (95% CI)**	**W (df)**	**B (SE)**	**AOR (95% CI)**
Country (Ireland), Ref = Sweden				5.778 (1)*	1.480 (0.616)	4.393 (1.314, 14.684)	6.636 (1)**	1.596 (0.620)	4.934 (1.465, 16.620)
Country (Kenya), Ref = Sweden				16.080 (1)**	2.448 (0.610)	11.564 (3.495, 38.258)	16.118 (1)**	2.462 (0.613)	11.724 (3.525, 38.996)
Country (Ireland), Ref = Kenya				3.911 (1)*	− 0.968 (0.489)	0.380* (0.146, .991)	3.088 (1)	− 0.865 (0.493)	0.421 (0.160, 1.105)
Conception: Technician									
Intercept	27.817 (1)**	− 0.830 (0.157)		55.059 (1)**	− 1.208 (0.163)		32.563 (1)**	− 1.104 (0.193)	
Gender	0.551 (1)	− 0.164 (0.221)	.849 (.550, 1.309)				.948 (1)	− 0.218 (0.223)	0.804 (0.519, 1.247)
Country (Ireland), Ref = Sweden				7.610 (1)**	0.669 (0.243)	1.952 (1.214, 3.141)	8.010 (1)**	0.690 (0.224)	1.994 (1.236, 3.215)
Country (Kenya), Ref = Sweden				1.286 (1)	0.378 (0.333)	1.459 (0.759, 2.803)	1.302 (1)	0.380 (0.333)	1.463 (.761, 2.811)
Country (Ireland), Ref = Kenya				0.727 (1)	0.291 (0.342)	1.338 (0.685, 2.615)	0.818 (1)	0.310 (0.342)	1.363 (.697, 2.666)
Conception: Tradesman									
Intercept	11.865 (1)**	− 0.484 (0.140)		73.751 (1)**	− 2.797 (0.326)		59.500 (1)**	− 2.620 (0.340)	
Gender	2.724 (1)	− 0.334 (0.202)	0.716 (0.482, 1.065)				2.961 (1)	− 0.385 (0.224)	0.680 (0.439, 1.055)
Country (Ireland), Ref = Sweden				41.377 (1)**	2.374 (0.369)	10.738 (5.210, 22.133)	42.369 (1)**	2.411 (0.370)	11.143 (5.392, 23.028)
Country (Kenya), Ref = Sweden				89.130 (1)**	3.576 (0.379)	35.744 (17.012, 75.102)	89.109 (1)**	3.581 (0.379)	35.906 (17.071, 75.521)
Country (Ireland), Ref = Kenya				21.427 (1)**	− 1.203 (0.260)	0.300 (0.181, 0.500)	20.144 (1)**	− 1.170 (0.261)	0.310 (0.186, 0.517)
Full model -2 Log likelihood	66.519			82.897			163.678		
Full model likelihood ratio	$\chi^2(6) = 17.807$, $p = 0.007$			$\chi^2(12) = 482.276$, $p < 0.001$			$\chi^2(18) = 503.972$, $p < 0.001$		
Cox and Snell R^2	0.016			0.362			0.375		
Nagelkerke R^2	0.017			0.373			0.386		
McFadden R^2	0.005			0.128			0.134		

*$p < 0.05$. **$p < 0.01$. Independent variable = Student conceptions of engineers. W = Wald. df = Degrees of freedom. SE = Standard error. OR = Odds ratio. AOR = Adjusted odds ratio. CI = Confidence interval. Gender reference = Male. Intercept calculated with Sweden as the reference country. Model 3 coefficients are adjusted for all covariates. N/A coefficients due to no drawings coded as scientists in the Irish sample

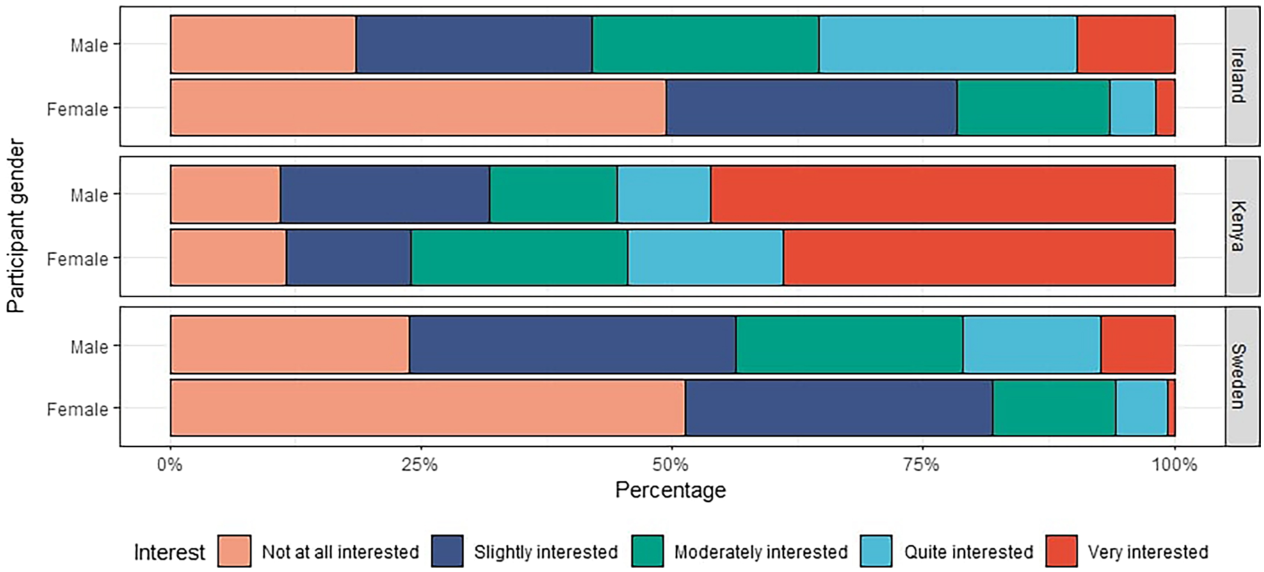

Fig. 4 Responses to the Likert item "how interested are you in being an engineer?" By students' gender and country

Table 6 Dunn's pairwise comparisons in interested in becoming an engineer

Pairwise comparison	Dunn's *z*
Irish females—Irish males	− 7.580**
Irish females—Kenyan females	− 12.346**
Irish males—Kenyan females	− 4.593**
Irish females—Kenyan males	− 12.778**
Irish males—Kenyan males	− 4.689**
Kenyan females—Kenyan males	0.088
Irish females—Swedish females	0.511
Irish males—Swedish females	7.437**
Kenyan females—Swedish females	11.790**
Kenyan males—Swedish females	12.120 **
Irish females—Swedish males	− 4.963**
Irish males—Swedish males	2.352
Kenyan females—Swedish males	6.838**
Kenyan males—Swedish males	7.012**
Swedish females—Swedish males	− 5.050**

*$p < 0.05$. **$p < 0.01$. z coefficients relate to unadjusted p values, e.g., $z = 1.96$ corresponds with $p = 0.05$ two-tailed. Asterisks relate to the Bonferonni adjusted alpha level of $\alpha_{adj} = 0.0033$ (0.05/15)

2013; Ergün & Doğukan Balçın, 2018; Fralick et al., 2009; Karatas et al., 2011; Knight & Cunningham, 2004; Koyunlu Ünlü & Dökme, 2017). The added insight gained from this work is in the comparisons that can be made between the included countries. Irish male and female students were more likely to draw a male engineer than Swedish and Kenyan male and female students, respectively, and there was an interaction effect such that male Kenyan students were more likely to draw a male engineer than male Swedish students, but female Swedish students were more likely to draw a male engineer than female Kenyan students. While the students' gender accounted for more variance in likelihood to draw a male engineer than the country they were from, including the students' country as a main effect and a gender × country interaction effect did add incremental validity beyond a main effect of gender alone. Therefore, there is a need to consider both young people's gender and their cultural context with respect to their stereotypical views on engineers' genders.

In terms of depicted conceptions of engineers, how engineers were stereotyped was very complex. Considering type of work, e.g., designing, site management, or manual labour, in conjunction with the field of work, e.g., civil engineering, computing engineering, or chemical engineering, resulted in 57 unique combinations reflecting a more nuanced depiction of the activity engineers were drawn as engaging in than considering just one approach to coding (Fig. 2). It was therefore decided to examine the conceptions of activity alone based on the intent of the coding scheme as described by Carr and Diefes-Dux (2012). Considering both country and gender in the model (Table 4; Model 3) explained 38.6% of the variance in the likelihood of representing an engineer as different conceptions. Interestingly, there was much similarity between Ireland and Kenya in that mechanics, labourers, technicians and tradespeople were depicted relatively frequently, with Kenyan students also depicting a significant number of scientists. In contrast the most frequent conception of an engineer from the Swedish students was that of a designer. While the amount

Table 7 Ordinal regression with interest in becoming an engineer as the dependent variable

	Model 1			Model 2			Model 3		
	W (df)	B (SE)	OR (95% CI)	W (df)	B (SE)	OR (95% CI)	W (df)	B (SE)	AOR (95% CI)
Gender	16.345 (1)**	− 0.421 (0.104)	0.657 (0.535, 0.805)				12.058 (1)**	− 0.364 (0.105)	0.695 (0.566, 0.853)
Country (Ireland), Ref = Sweden				0.029 (1)	− 0.022 (0.132)	0.978 (0.756, 1.266)	0.001 (1)	− 0.005 (0.132)	0.995 (0.768, 1.288)
Country (Kenya), Ref = Sweden				94.866 (1)**	1.313 (0.135)	3.718 (2.855, 4.843)	93.285 (1)**	1.302 (0.135)	3.677 (2.823, 4.790)
Country (Ireland), Ref = Kenya				109.392 (1)**	− 1.336 (0.128)	0.263 (0.205, 0.338)	104.760 (1)**	− 1.307 (0.128)	0.271 (0.211, .348)
Full model -2 Log likelihood	100.860			232.399			400.284		
Full model likelihood ratio	$\chi^2(1) = 16.389$, $p < 0.001$			$\chi^2(2) = 132.256$, $p < 0.001$			$\chi^2(3) = 144.268$, $p < 0.001$		
Cox and Snell R^2	0.014			0.106			0.115		
Nagelkerke R^2	0.014			0.111			0.120		
McFadden R^2	0.004			0.036			0.039		

*$p < 0.05$. **$p < 0.01$. Independent variable = Interest in becoming an engineer measured through a 5-point Likert item (1 = not at all interested, 5 = very interested). W = Wald. df = degrees of freedom. SE = standard error. OR = odds ratio. AOR = adjusted odds ratio. CI = confidence interval. Gender reference = male. Intercept calculated with Sweden as the reference country. Model 3 coefficients are adjusted for all covariates. N/A coefficients due to no drawings coded as scientists in the Irish sample

of variance explained by gender alone (1.7%) was much lower than was explained by country alone (36.2%), there were statistically significant country level differences when controlling for students' gender, illustrating again the necessity of considering both a young person's gender and the country they are from with respect to their understanding of engineers and engineering.

The analysis in which students' interest in becoming an engineer was examined also revealed interesting observations. There was not a statistically significant difference between Irish and Swedish students' interest in becoming an engineer in the future, but Kenyan students were approximately 3.6 times more interested in becoming an engineer than students from either of the other two countries. Within both Ireland and Sweden, males were statistically more interested in becoming an engineer, but there was not a significant gender difference between male and female Kenyan students.

Finally, considering interest in becoming an engineer relative to the comparison between the gender of drawn engineers and the students' own gender also revealed interesting insights and suggests predictive validity, particular for female students, in the DAET with respect to their interest in becoming an engineer. There was an association between the gender of drawn and interest in becoming an engineer for female but not male students. For females who drew a male engineer, 43.6% were "not at all interested" in becoming an engineer whereas 18.2% were either "quite interested" or "very interested". In contrast, only 24.5% of females who drew a female engineer were "not at all interested" in becoming an engineer whereas 30.5% were either "quite interested" or "very interested". For male students across all three countries, this contrast in interest between students who drew an engineer as either the same or a different gender to their own was not apparent as in either case there was more interest in becoming an engineer than not. For male students who drew a female engineer, 33.3% were either "quite interested" or "very interested" in becoming an engineer in contrast to 16.7% who were "not at all interested", and for male students who drew a male engineer, 40% were either "quite interested" or "very interested" in becoming an engineer in contrast to 17% who were "not at all interested. These results suggest that, particularly for young females, associating engineering as an occupation inclusive to females or at least not holding a strong stereotype that there is a barrier to females, i.e., they

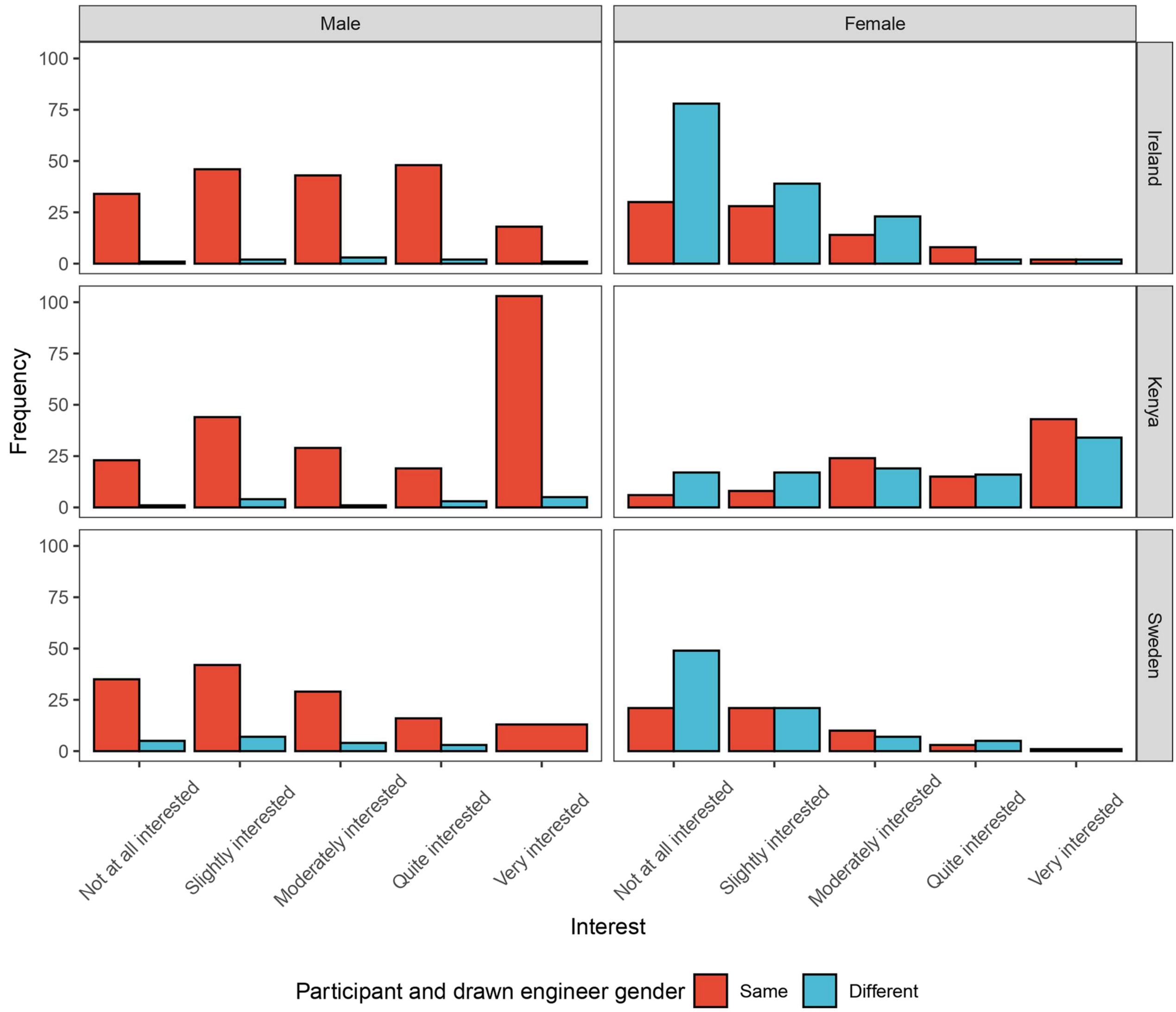

Fig. 5 Comparison of students' self-reported gender and gender of drawn engineers (same or different) across levels of reported interest in becoming an engineer

can "see themselves" in the profession, relates positively to their interest in becoming an engineer.

For male and female students in both Ireland and Sweden, but not in Kenya, a significant association also existed in this regard. In Ireland, 51.6% of students who drew an engineer of a different gender to their own were "not at all interested" in becoming an engineer. In contrast, only 23.6% of students who drew an engineer of the same gender to themselves were "not at all interested" in becoming an engineer. These percentages were similar in Sweden, where 52.9% of students who drew an engineer of a different gender to their own and where 29.5% of students who drew an engineer of the same gender to themselves were "not at all interested" in becoming an engineer. In Kenya, similar to male students in general, this contrast was not apparent and there was generally more interest in becoming an engineer than not. For Kenyan students who drew an engineer of a different gender to their own, 49.5% were either "quite interested" or "very interested" in becoming an engineer in contrast to 15.4% who were "not at all interested", and for Kenyan students who drew an engineer of the same gender to their own, 57.3% were either "quite interested" or "very interested" in becoming an engineer in contrast to 9.2% who were "not at all interested".

Implications for research and practice

Previous work using the DAET instrument has focused on individual countries, notably Mexico (Carreño et al., 2010; Cruz López et al., 2011, 2013), Turkey (Ergün & Doğukan Balçın, 2018; Koyunlu Ünlü & Dökme, 2017), and the US (Diefes-Dux & Capobianco, 2011; Fralick et al., 2009; Oware et al., 2007). This study extends this work by presenting data from students in Ireland, Sweden, and Kenya. Further, the inclusion of students from multiple countries allowed for the effects of their gender and the country they were studying in to be explored together relative to the gender and conception of drawn engineers, and to the students' interest in becoming an engineer in the future. The results of this work indicate that students' self-reported gender explains more variance in the gender of drawn engineers and that the country they were studying in explains more variance in their conception of engineers. However, most variance is explained when both students' gender and country of study are considered together.

With respect to the gender of drawn engineers, it should be noted that when asked to draw a person generically with no occupation, prior studies have found that usually 70% or more of both boys and girls have drawn their own sex (Arteche et al., 2010; Picard, 2015). In prior DAET studies, including in this study, males have been observed to draw male engineers at a similar and higher rate, however females have been found to draw female engineers 25–50% of the time (Capobianco et al., 2011; Carreño et al., 2010; Ergün & Doğukan Balçın, 2018; Knight & Cunningham, 2004). This could suggest that while both males and females can see themselves as engineers, females do to a lesser extent. Given the relationship between a young persons' self-concept and their interest and subsequent engagement in a field (Guo et al., 2017; Murphy et al., 2019) it is paramount that young people, in particular young females in the case of engineering, see the field as one they can enter. Factors such as engineering culture (Carberry & Baker, 2018) and internal field-specific ability beliefs (Leslie et al., 2015) can perpetuate a false message of "who" can become an engineer and create an implicit barrier to women (Simmons & Lord, 2019). The DAET can offer insight into whether young people of different demographics see engineering as an inclusive environment and be a catalyst for discourse on what an engineer is and does. This is particularly important at stages of education when decisions are being made which affect future career dispositions and orientations. Importantly, while the results of this study do indicate that a students' gender is the most important factor in predicting their engineer gender-stereotypes, the country they are living in does have influence. However, these results need to take young people's conceptions of engineers into account as, for example, girls in Ireland or Kenya may or may not see themselves as an engineer when they stereotype engineers as mechanics or tradespeople, whereas girls in Sweden may or may not see themselves as an engineer when they stereotype engineers as designers.

The findings of this study pertaining to how the students conceived the nature of work engineers engaged with were also interesting in that, at a country level, there were dominant stereotypes (Fig. 3). In Ireland the dominant depiction of engineers were as mechanics, and this was followed by designers and then tradesmen. In Kenya the profile of engineer conceptions was similar to that from the Irish students. The majority of drawn engineers were again presented as mechanics, but there were also a relatively high portion of tradesmen and scientists. In Sweden, the vast majority of students represented an engineer as a designer, which was in contrast to both Ireland and Kenya. While there were differences between countries, within each country there was a dominant engineer stereotype (a mechanic/tradesperson in the cases of Ireland and Kenya and a designer in the case of Sweden). It is important to consider the possible sources of these stereotypes, and a probable main source appears to be exposure to engineering-related education at secondary level. In Ireland, as discussed there is an explicit but optional subject called Engineering which often sees students manufacturing vehicles. This would appear to correspond to the Irish students' stereotyping of an engineer as a mechanic. In Sweden, there is no explicit Engineering subject, however there is a subject called Technology, and this is mandatory for all students at compulsory school level (ages $\approx$ 7–15). The Technology subject does place an emphasis on students designing technological systems to solve problems, and there is a large focus on technology in broader society. It would appear that this subject—which is probably the closest in nature to engineering to affect a stereotype—could have influenced the students to associate engineering with designing (often represented as technical/engineering drafting in their drawings) at a societal level. In Kenya, there is no subject immediately associated with engineering or craft in the secondary school curriculum. Like in Ireland and Sweden however all students study the natural sciences. It is possible the absence of an engineering-related subject resulted in a large portion of Kenyan students illustrating a scientist as a heuristic due to no prior experience of engineering. These findings do offer support for interventions to inform people about engineering taking place at lower secondary level.

There is a lack of diversity in many engineering fields internationally (Berge et al., 2019; Moloney & Ahern, 2022; Peixoto et al., 2018; Yoder, 2017), but there is also quite a lack of diversity in how engineers are stereotyped within countries. Given that at the time of data collection the participating students would have been or about to be making decisions on upper-secondary level subjects of courses, a decision which is associated with future higher education field enrolment (Chachashvili-Bolotin et al., 2016; Jacob et al., 2020; Wang, 2013), there appears a need to further clarify the diverse nature of engineering to students. This could be achieved in a variety of ways, such as by introducing students to engineering role models and providing a forum for students to converse with engineers (e.g., Engineer Girl, 2022), or by having information on various engineering fields dissemination through career guidance education.

The implications of these findings become increasingly apparent when considered through the lens of the students' levels of interesting in becoming an engineer. Particularly for female students, a significant relationship was observed between their interest in becoming an engineer and whether they drew an engineer of the same or a different gender to their own self-reported gender. This further highlights the importance for young females of seeing engineering as a place for women. However, there is added complexity in this regard as while the students were all asked the same question, they may not have interpreted it the same way. For example, Irish females were generally less interested in becoming an engineer than Irish males, but they typically stereotyped engineers as mechanics or tradespeople. Similarly, Swedish females were also generally less interested than Swedish males in becoming an engineer, but they typically stereotyped engineers as designers. It is not clear whether the students would have responded as they did if the diverse nature of engineering was elaborated on to the students prior to the survey. It may not be that Irish female students, for example, are not interested in becoming an engineer but are instead not interested in becoming a mechanic, and this is similar for all students in the study with reference to their own personal stereotypes. This is equally important for the students who said they were interested in becoming an engineer in the future. These students may find, after making critical educational decisions, that as they gain a better understanding of what it can mean to be an engineer in different fields that they really are not interested and would instead prefer to be a mechanic or an architect for example. Further research on the impact of informing students about engineering on their interest in it is warranted, as is further research which examines students' interest in becoming an engineer at a more nuanced, perhaps field-specific, level.

Finally, beyond the interaction between level of interest in becoming an engineer and a young person's conception of an engineer and gender, the cultural context they are in with respect to the educational system, economy and occupational choice options needs to be considered. Young people from Ireland and Sweden have, in general, easier access routes to third level education and by virtue of their economies there is an increased level of occupational choice and there can be less pressure on when to make future career related choices. In Kenya, the opportunity to access higher education is life changing. It does not matter as much what type of education a person gets and choosing according to interest is often a luxury. Higher education means a person can become financially independent. It is probable that the Kenyan response to being interested in becoming an engineer is more a response to interest in access to third level education, which is why there is no significant gender difference, and the general response was to be very interested. In contrast, the Irish and Swedish students would have had the luxury of not being interested in becoming an engineer. It would therefore be important for future related work to differentiate between general and disciplinary interest in education, and for future work to gain further insight into interest in engineering in developing countries from a broader sociocultural perspective.

Conclusion

The results reported from this study offer important insight regarding the importance of informing students about the nature of engineering early in their education. Many such interventions exist which aspire to promote interest in engineering. There is, however, the added agenda of ensuring students are adequately informed about future career possibilities and what these involve when making choices, such as subject choices, which could impact their interest capacity to enter certain professions in their future. It is just as important to inform a student about engineer to inspire them to become a future engineer as it is to inform them of the profession so they can be more certain if engineering is not what they are interested in. Another important implication of this work pertains to the identification of factors associated with engineer stereotypes. A student's own gender was most strongly associated with their engineer-gender stereotypes, whereas the country they were studying in was most strongly associated with their stereotypes of engineering work. It is speculated that lower secondary education systems are a large contributing factor to these stereotypes, but further work is needed to identify their sources more clearly. Importantly, cultural context as it relates to educational opportunities of students needs to be considered so as not to conflate specific interest in engineering with general interest in improving one's life through higher education. Given the variances in engineering-work stereotypes, future work relating to interest in engineering should also be cognizant of the difference between student conceptions of engineers after informative interventions and those where no explicit informative information is provided.

Finally, it is important to view this work with its associated limitations in mind. First, while popular and generally regarded as valid instruments for eliciting stereotypes, the argument that "Draw-a" instruments are limited by only asking for a depiction of one archetype should be taken into account. Further, samples were not stratified relative to national populations. As a result, more discrete analysis into sub-cultures within the included countries was not possible and the results may not generalise to certain demographics or sub-cultures. Finally, as noted this study stops short of gaining explicit insight into why students from the different countries viewed engineers as they did. Future work should consider this from a sociocultural perspective as the messaging around engineering that is presented, either implicitly or explicitly, within a country is of importance in how the profession is stereotyped.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40594-023-00416-9.

Additional file 1: Table S1. Frequency of variations in drawn engineers by Irish males.

Additional file 2: Table S2. Frequency of variations in drawn engineers by Irish females.

Additional file 3: Table S3. Frequency of variations in drawn engineers by Kenyan males.

Additional file 4: Table S4. Frequency of variations in drawn engineers by Kenyan females.

Additional file 5: Table S5. Frequency of variations in drawn engineers by Swedish males.

Additional file 6: Table S6. Frequency of variations in drawn engineers by Swedish females.

Additional file 7: Table S7. Multinomial logistic regression with the conception of drawn engineers as the dependent variable.

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Author contributions
JB was responsible for the conceptualization of the study, methodological design, data collection, data analysis, writing the original draft, and editing. LG was responsible for the conceptualization of the study, methodological design, data collection in Sweden, writing the original draft, and editing. MN was responsible for data collection in Kenya and contributed to the original draft. TH collected data in Ireland, and contributed to data analysis and editing of the original draft. NS collected data in Ireland and edited the original draft. AP contributed to the original draft and subsequent editing. All authors read and revised the manuscript critically for important intellectual content. All authors have given approval for the final manuscript to be published.

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Availability of data and materials
The Draw-an-Engineer-Test instruments used in this study, and Tables S1–S7 are available in the project OSF storage at https://osf.io/dkqyn/. The datasets generated and analysed during the current study are not publicly available as open sharing was not requested in the ethics application but are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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