GENDER DIFFERENCES IN ATTITUTES TOWARDS ENGINEERING STUDIES AND IN GRADUATES

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ABSTRACT

Gender difference in Science, Technology, Engineering and Mathematics (STEM) education is well reported and analysed, and models and recommendations have been put forward. Research has revealed that different engineering programs are more attractive to one gender than the other and understanding university students' attitudes towards STEM is essential for changing this situation. Choice of studies can be difficult because so many factors are involved, e.g. peer pressure, stereotypes, access and availability and local cultural expectations. This paper seeks to ascertain if there is a gender difference in engineering students' attitudes toward engineering, and if the development of gender balance has been changing during the last decade in the different engineering fields. Survey data was collected from students enrolled in a university engineering program at Reykjavik University, Iceland, and available data on the number of graduates between 2008 and 2021 were analysed. The results show that the genders may have divergent interest in different disciplines of engineering which is reflected in quite different gender ratios at graduation, but at the same time there is a systematic change during the last decade in some engineering disciplines. Furthermore, females are getting interested in engineering education significantly later than males, but the genders report similar reasons for choosing engineering education. This topic touches on CDIO Standard 1 (program philosophy), 7 and 8 (new methods of teaching and learning).

KEYWORDS

STEM, gender difference, engineering, CDIO standards 1, 7, 8.

INTRODUCTION

Gender difference in Science, Technology, Engineering and Mathematics (STEM) has slowly decreased over the years, but is still of considerable concern. In engineering the situation is different in different countries and even universities and different engineering programs appeal differently to the genders. Female students and professionals are often around 10 – 25% in the engineering field in many parts of the world. As an example, in the UK, women were 14.5% of all engineers in 2021, an increase by 25.7% since 2016 (SWE, 2021). In the USA, women where 22.5% of bachelor's graduates in 2019 and the enrolment was 23.8% (American Society for Engineering Education, 2020). In Japan, women have been 9-10% of graduated engineering students, but only around 1% of working engineers (Balakrishnan, 2014). Lichtenstein et al. (2014) phrase it well when they say, "… in spite of a policy agenda targeted

at boosting participation of women and underrepresented minorities in the engineering workforce, progress has been slow" (p. 325–326).

According to González-González et al. (2018) the five most common barriers that women encounter in engineering education are: lack of mentors, lack of female role models in the field, gender bias in the workplace, unequal growth opportunities compared to men, and unequal pay for the same skills. To understand the situation today and the driving forces for this development it can be helpful to analyse engineering students' attitudes to the discipline of engineering. This could lead us in the effort to recruit not only more females in STEM, and especially engineering and applied engineering, but more students overall.

The objective of this study was to ascertain with a survey if BSc students reported different attitudes toward engineering depending on gender and line of study. These results are then compared to how gender ratios have evolved for graduates in the last 14 years at Reykjavik University (RU). More specifically, the two research questions are: Is there a gender difference in students' attitudes toward engineering? and Has the development of gender balance been changing for the last decade in different engineering fields?

RELATED WORK

STEM is recognized as a driving force for innovation and the economy; thus, it is important to attract more students and promote equality, diversity, and inclusion (EDI) in the field. Although more women are attending STEM, their interest seems to be mainly in health-related disciplines and life sciences and they have been underrepresented in math, physical science, engineering, and computer science (Matthiasdottir & Palsdottir, 2016; Funke, Berges, & Hubwieser, 2016; Lin, Ghaddar, & Hurst, 2021).

STEM fields have very diverse cultures (Cheryan et al., 2017). The masculine culture of engineering and a lack of role models and community for women has characterised the field for a long time (Robinson, & McIlwee, 1991). Anyhow, more women are attending engineering education today than before, but the development has been rather slow. In 2018, 85% of bachelor's degrees in health-related fields were to women, but only 22% in engineering (Fry, Kennedy, & Funk, 2021). According to American Society for Engineering Education (ASEE, 2021) report, Profiles of Engineering and Engineering Technology, females where 17.8% of bachelor's graduates in 2010 and 23.1% in 2020 in the USA. In Spain, 29% of students in engineering and architecture were women (Previo, 2017). One can even find an example of a university in Sweden were 39% of the students in engineering were females (Peixoto et al., 2018).

Universities offering engineering education have a variety of study lines for students to choose from and the gender balance in the programs are different. In a new SWE (Society of Women Engineering) report, the top five engineering degrees awarded to women in the USA in 2019 were 1) Mechanical engineering, 2) Chemical engineering, 3) Computer science, 4) Biomedical engineering, and 5) Civil engineering (SWE, 2021). The situation is a little bit different in a report from the American Society for Engineering Education (ASEE, 2021), where the top five bachelor's degrees in 2020 awarded to women in the USA by discipline were 1) Environmental engineering, 2) Biomedical engineering, 3) Biological and agricultural engineering, 4) Chemical engineering, and 5) Industrial/Manufacturing/Systems (ASEE, 2021). At Chalmers University in Sweden, 61% of female students attended Industrial Engineering Design, but only 8% Marine Engineering. In Canada in 2004, the highest proportions of women in engineering sub-

disciplines were in biosystems, environmental, chemical, and geological engineering, and all these four were still in the top quartile in 2017. On the other hand, he lowest proportions of women in Canada 2004 and 2017 were in electrical, computer, software, and mechanical engineering (Sweeney, 2020). This shows that the trend is different between countries but one must keep in mind that the classification and names of similar sub-disciplines can be somewhat different.

Deciding on an academic study or a career is easy and straight forward for some individuals, especially when they have an interest and knowledge of the profession of choice earlier on. For others, this can be a provocative and strenuous project because of the many influencing factors. In an Icelandic study from 2018, 70% of the students said they got interested in engineering between 15 and 22 years of age (Matthiasdottir, 2018). Cruz and Kellam (2018) found out that students seemed to have limited understanding of what is involved in an engineering program in the USA before they started their study and Salas-Morera et al. (2021) concluded that high school students are not well informed about engineers' work and girls less than boys. To know when students develop interest in their field of study is relevant for those who want to reach out and introduce engineering to potential students.

Research has revealed different factors that influence the gender differences in choices of academic studies. In particular, the study by Cheryan et al. (2017) revealed forces, both within STEM (e.g., role models) and outside STEM (e.g., cultural stereotypes about these fields), that direct both women and men into some of the STEM fields. In a study from 2018, it appeared that males had more interest in the engineering profession, but females were more influenced by their success in science at earlier educational levels (Matthiasdottir, 2018). The model by Cheryan, Ziegler, Montoya and Jiang's (2017) to explain gender gaps in computer science, engineering, and physics is based on three factors: "(a) masculine cultures that signal a lower sense of belonging to women than men, (b) a lack of sufficient early experience with computer science, engineering, and physics, and (c) gender gaps in self-efficacy". They do emphasise that these factors may also be helpful to analyse gender differences in fields where men are underrepresented.

METHOD

The data used in this study originates from two sources. First, a survey was conducted among engineering students in the BSc program in engineering at Reykjavik University (RU), and second, data was obtained from the university registry on the number of students graduating with particular engineering sub-discipline. The BSc engineering program at RU is a 3-year program, and it follows the Bologna three-cycle degree structure

Survey

Participants

An online survey was e-mailed to 478 students that were registered in the bachelor program in engineering at RU. In total 124 (26%) replied, 64 (51.2%) males and 57 (45.6%) females. Four did not indicate their gender. The males' average age was 22.4 (sd=4.0; range=19-45) years and the females' 21.3 (sd=1.9; range=18-28) years. Thirty-two 32 (26.9%) were first year students, 55 (37.8%) second year, 38 (31.9%) third year and 4 (3.4%) fourth year, and the response rate between genders appeared not significant (Chi-square=1.16, p=0.76).

Measures

The online survey consisted of nine questions partly designed for this study and partly based on one of the author's study from 2018 (Matthiasdottir, 2018), with similar objectives as the current survey. The survey included students in both engineering (as in the current survey) and in applied engineering, but the latter group is more male dominated and includes a bit older students. The four background questions were on gender, age, line of study and year of study, and the five following questions concerning the participant's experience and attitudes:

- *Why did you choose to study engineering?* Thirteen answering options were given and the participant was instructed to select the three most relevant for him/her without ranking them.
- *Was something else than engineering an option?* The answering options were: yes, no, If yes, then what?
- *When did you first get interested in engineering?* Four age categories were provided: younger than 14, 15-18, 19-22 and older than 22.
- *What image did you have of engineers before you started your studies*? Eleven answering options were given and the participant was instructed to select the three most relevant for him/her without ranking them.
- *How much computer skills do you consider you had before you started to study engineering?"* This question was rated on a five point Likert scale, ranging between "Great skills" and "Very little skills". The term "computer skills" was not defined in the questionnaire and the participant could select one answer.

Of these five questions, all except the one on the image of engineers were in the survey by Matthiasdottir (2018).

Procedure

The system Free Online Surveys (https://freeonlinesurveys.com) was used to put the survey online and a link was sent to the participants by e-mail on the 2th December 2021 and a reminder on the 20th December. Teachers were also asked to encourage students to answer the survey. The survey was closed on the 30th of January 2022. Data analysis was carried out in Excel and the Statistical Package for the Social Sciences (SPSS).

Graduating students

The engineering department registry office provided information on students that graduated from the bachelor program in engineering. The data was for the years 2008-2021 and classified by gender and different sub-disciplines.

RESULTS

Survey

Table 1 shows the distribution of the genders between sub-disciplines in engineering as reported in the survey. Biomedical engineering is the most popular among the females (39.3%), but mechatronics engineering (28.1%) among the males. Second most popular discipline for the males is financial engineering (25.0%), but engineering management (26.6%) for females.

Table 1. Participants reported sub-disciplines according to gender.

	Male N (%)	Female N (%)	Total N (%)
Financial engineering	16 (25.0)	5 (8.9)	21 (17.5)
Mechatronics Engineering	18 (28.1)	4 (7.1)	22 (18.3)
Biomedical Engineering	10 (15.6)	22 (39.3)	32 (26.7)
Energy engineering	1 (1.6)	1 (1.8)	2. (1.7)
Electrical engineering	1 (1.6)	0 (0)	1 (0.8)
Engineering Management	7 (10.9)	16 (26.6)	23 (19.2)
Mechanical engineering	8 (12.5)	4 (7.1)	12 (10)
Software engineering	3 (4.7)	4 (7.1)	7 (5.8)

Both males and females selected the same top four reasons for choosing engineering education, i.e. “interesting profession” (56.3/38.6%), “interested in science” (53.1/40.4%), “good salaries” (50.0/43.0%), and “good employment outlook” (48.4/43.9%) as shown in Table 2. The gender difference was only significant for “interest in math”, which was chosen by 38.6% of females and 20.3% by males (*p<0.05).

Table 2. The participants’ reason for selecting engineering education.

	Male	Female	
	Yes N (%)	Yes N (%)	Chi-Square
Interesting profession	36 (56.3)	22 (38.6)	3.76
Good employment outlook	31 (48.4)	25 (43.9)	0.25
Good salaries	32 (50.0)	25 (43.0)	0.46
Interested in math	13 (20.3)	22 (38.6)	4.90*
Interested in computers	10 (15.6)	5 (8.8)	1.30
Interested in science	34 (53.1)	23 (40.4)	1.97
Did well in math in upper secondary school	13 (20.3)	19 (33.3)	2.63
I just wanted to try	6 (9.4)	11 (19.3)	2.46
Diversified profession	17 (26.6)	14 (26.6)	0.06
There has never been anything else	6 (9.4)	5 (8.8)	0.01
I was encouraged by others	2 (3.1)	5 (8.8)	1.76
Familiar with the subject through my family	5 (7.8)	3 (5.3)	0.32

Participants were asked if they had considered to study another subject at university and the most frequent subject mentioned was medicine (mentioned by 13 participants of which 8 were students in biomedical engineering).

Table 3 shows when participants felt they got interested in engineering education. There was a significant different between the genders (Chi-Square= 11.59 p<0.01), the females reporting higher age than the males.

Table 3. Gender and age when participants claimed they got interested in engineering education.

	Male N (%)	Female N (%)	Total N (%)
Younger than 14 years	13 (20.3)	1 (1.8)	14 (11.6)
15-18 years old	29 (45.3)	27 (47.4)	56 (46.3)
19-22 years old	18 (28.1)	26 (45.6)	44 (36.4)
Older than 22 years	4 (6.3)	3 (5.3)	7 (5.8)

Table 4 describes the participants reported image of engineers before they started their study. Both groups, males and females, reported solution-oriented (87.5/77.2%) and good at math (76.6/80.7%). Only the "masculine" image revealed significant difference (*$p < 0.05$). One participant added an item to the image list and said that his image of engineers was "nerds".

Table 4. The participants reported image of engineers before starting their study in engineering.

	Male N (%)	Female N (%)	Chi-Square
Masculine	10 (15.6)	19 (33.3)	5.19*
Feminine	0 (0)	1 (1.8)	-
Neither masculine nor feminine	6 (9.4)	11 (19.3)	2.46
Good at math	49 (76.6)	46 (80.7)	0.31
Tidy	4 (6.3)	3 (5.3)	0.05
Solution-oriented	56 (87.5)	44 (77.2)	2.23
Foresighted	22 (34.4)	12 (21.1)	2.65
Promote innovation	33 (51.6)	22 (38.6)	2.04
Promote sustainability	5 (7.8)	7 (12.3)	0.67
Formative	14 (21.9)	16 (28.1)	0.62

Table 5 describes how skilled the participants said they were before they started their study. As the table shows, 14.3% of the males considered them to have great computer skills before they started, but only 3.5% of the females. The difference appeared significant (Chi-Square = 10.42, $p < 0.05$).

Table 5. The participants' computer skills before they started studying engineering at university.

	Male N (%)	Female N (%)	Total N (%)
Great skills	9 (14.3)	2 (3.5)	11 (9.2)
Many skills	20 (31.7)	9 (15.8)	29 (24.2)
Average skills	18 (28.6)	27 (47.4)	45 (25.4)
Little skills	12 (19.0)	14 (24.6)	26 (21.7)
Very little skills	4 (6.3)	5 (8.8)	9 (7.5)

Graduating students

Table 6 shows how many female students graduated between 2008 and 2021 from the engineering department and the trend over the last 14 years (since the program started at RU).

Table 6. Female BSc engineering graduation between 2008 and 2021.

	Financial engineering	Mechatronics Engineering	Biomedical Engineering	Mechanical engineering	Engineering Management
Female	81 (33%)	48 (21%)	197 (77%)	11 (17%)	210 (55%)
Linear trend (%/year)	-0.8	2.1	0.1	4.4	0.9

Figure 1 shows the proportion of female students graduating from sub-disciplines from 2008 to 2021. Due to the low number of students, there are fluctuations in the number of graduates, but nevertheless when viewed with time like in Figure 1 there are clear trends for several of the programs.

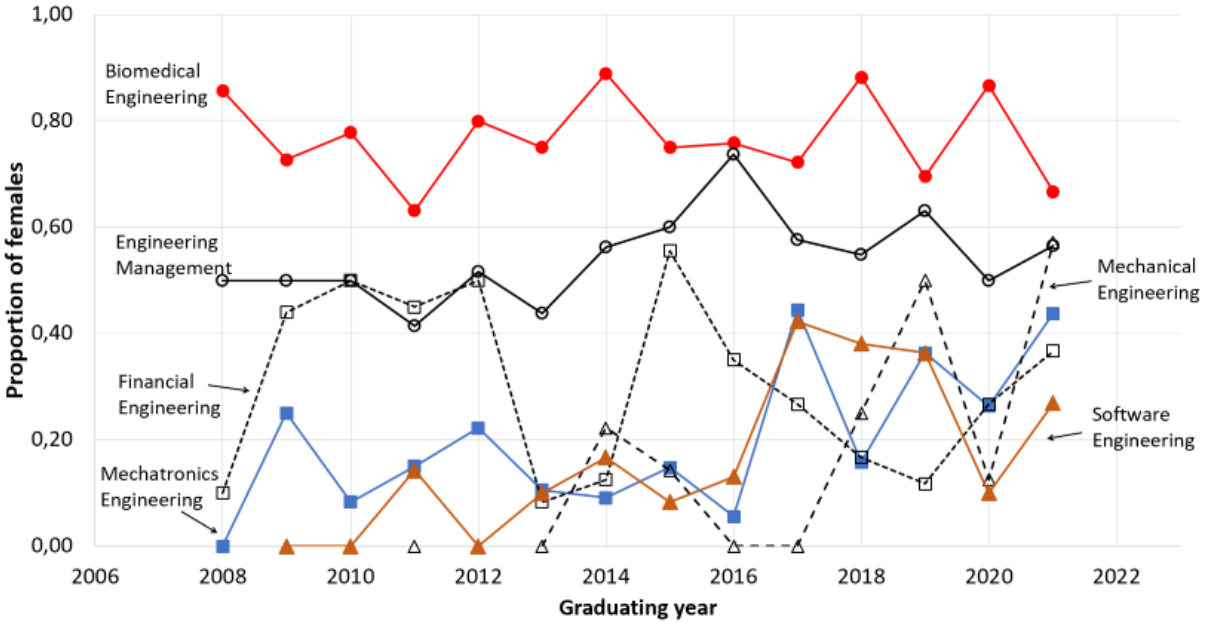

Figure 1 Proportion of females graduating from six engineering sub-disciplines during the years between 2008 and 2021.

DISCUSSION

The two main research question of the study where: Is there a gender difference in students' attitudes toward engineering? and Has the development of gender balance been changing for the last decade in different engineering fields?

The survey shows clearly a difference in what sub-discipline the genders select, biomedical engineering being the most popular among the females and mechatronics engineering among the males, who put biomedical engineering in the third place (Table 1). These results are consistent with the number of graduating students (Figure 1). The results are in line with the ASEE report, Profiles of Engineering and Engineering Technology from 2021 (ASEE, 2021). Research has shown that women are more interested in health-related subjects than males (Funke, Berges, & Hubwieser, 2016; Lin, Ghaddar & Hurst, 2021). The proportion of females in each graduating class in biomedical engineering has been amazingly high (77% females)

and stable since the program started in 2005. It is worth mentioning that at RU the term for the discipline “biomedical engineering” when literally translated is “health engineering” (in Icelandic “heilbrigðisverkfræði”), and the program is based on similar foundation as for example mechatronics engineering, but has courses on physiology and biomedical engineering. Names of programs can influence students’ interest and especially women (Farrell, 2002; Brown, 2014) so this can partly explain why biomedical engineering is so popular among female students in Iceland. Moreover, there are nil or few role models in biomedical engineering in Iceland and for a long time all the faculty in biomedical engineering at RU were males (one female faculty joined the team two years ago).

The genders agreed on the main reasons for choosing engineering education, namely that it is an interesting profession with good job opportunities and good salaries, but one significant difference appeared. The females reported more frequently that interest in math was one of their reasons for choosing engineering at university which is in line with previous studies in Iceland (Matthiasdottir, 2018). It may be of interest that studies show that negative attitudes towards math among females seem to have declined over the years (Jacobs, 2005; Huang, Zhang & Hudson, 2019). Research has suggested that computer use in education can impact educational performance and could encourage more technology self-efficacy among students (Paino & Renzulli, 2013; Matthiasdottir, 2018). And once again, males reported better computer skills than females which has appeared in many studies before.

This study shows that females and males both view engineers before entering engineering as “solution-oriented and “good at math”. On the other hand, females in this study reported more masculine image of engineers before starting university and that they became interested in engineering education significantly later than males. This may give an indication when and how we should introduce engineering to students. In view of current popular discussion, it is worth noting that “promote sustainability” was ranked low for both groups, which is something worthwhile to look into regarding interest in STEM education, but is outside the scope of this paper. Overall, the results from the current survey are consistent with the survey by Matthiasdottir (2018) for the questions that are the same, bearing also in mind that the surveyed population is somewhat different. This further supports the results and conclusions in this study despite a low participation rate.

Pros and cons of online data gathering has been discussed for decades and as Lefever, Dal and Matthíasdóttir (2006) pointed out there are factors as for instance participants age, gender, interest and maturity that can influence the response rate. Despite some limitations of the survey, especially the limited participation, the main trends appeared clear and distinct, and in addition are consistent with previous survey (Matthiasdottir, 2018). Therefore, we believe that the results in the survey gives us a good idea of the situation and can guide us in working toward more equality in STEM education.

The trends in graduates as shown in Figure 1 show that although the ratio of graduating females is low in mechatronics, mechanical engineering and software engineering, the proportion of females appears to be increasing for the last decade. At RU at least, in some fields of engineering females dominate and in others males dominate, but the trend is in the right direction towards improved equality.

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REFERENCES

ASEE (American Society for Engineering Education. (2021). *Profiles of engineering and engineering technology*. Washington, DC. https://ira.asee.org/wp-content/uploads/2021/11/Total-by-the-Number-2020.pdf.

Balakrishnan, B. (2014). Female engineering students' perception on engineering programme and profession: a case study in Malaysia and Japan. *In 8th International Technology, Education and Development Conference* (Valencia, Spain. 10-12, March) IATED.

Brown, K. V. (2014). Tech shift: More women in computer science classes. *San Francisco Chronicle* https://www.sfgate.com/education/article/Tech-shift-More-women-in-computer-science-classes-5243026.php.

Cheryan, S., Zieger, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin*, 143(1), pp. 1–35. https://doi.org/10.1037/bul0000052.

Cruz, J. & Kellam, N. (2018). Beginning an engineer's journey: A narrative examination of how, when, and why students choose the engineering major. *Journal of Engineering Education*, 107(4). Pp. 556-582.

Farrell, E. F. (2002). Engineering a warmer welcome for female students. *Chronicle of Higher Education,* 48(24), pp A31-A32.

Fry, R., Kennedy, B. & Funk, C. (2021). STEM jobs see uneven progress in increasing gender, racial and ethnic diversity. *Pew Research Center*, www.pewresearch.org.

Funke, A., Berges, M., & Hubwieser, P. (2016). Different perceptions of computer science. Pp. 14–18. *IEEE*. https://doi.org/10.1109/LaTiCE.2016.1.

González-González, C.S., García-Holgado, A., de los Angeles Martinez-Estévez, M., Gil, M., Martín-Fernandez, A., Marcos, A., Aranda, C., & Gershon, T. S. (2018). Gender and engineering: Developing actions to encourage women in tech. *IEEE Global Engineering Education Conference* (EDUCON) *2018,* pp. 2082-2087, doi: 10.1109/EDUCON.2018.8363496.

Huang. X., Zhang, J. & Hudson, L. (2019). Impact of math self-efficacy, math anxiety, and growth mindset on math and science career interest for middle school students: the gender moderating effect. *European Journal of Psychology of Education*. 34:621-640, https://doi.org/10.1007/s10212-018-0403-z.

Jacobs, J. E. (2005). Twenty-five years of research on gender and ethnic differences in math and science career choices: What have we learned? *New Directions for Child and Adolescent Development.*

Lefever, S., Dal, M. & Matthíasdóttir, Á. (2006). Online data collection in academic research: advantages and limitations. *British Journal of Educational Technology*, 38(4), pp. 574-582. doi.org/10.1111/j.1467-8535.2006.00638.x.

Lichtenstein, G., Chen, H., Smith, K., & Maldonado, T. (2014). Retention and persistence of women and minorities along the engineering pathway in the United States. In A. Johri & B. Olds (Eds.), *Cambridge Handbook of Engineering Education Research*, pp. 311–334. Cambridge University Press. DOI: https://doi.org/10.1017/CBO9781139013451.021.

Lin, B., Ghaddar, B. & Hurst, A. (2021). *Text mining undergraduate engineering programs' applications: the role of gender, nationality, and socio-economic status*. arXiv:2107.14034v3 [cs.CY] 21.

Matthiasdottir, A. (2018). Gender differences in engineering students´ choice of studies. Proceedings at *14th International CDIO Conference,* Kanazawa Institute of Technology, Kanazawa in Japan.

Matthiasdottir, A., & Palsdottir, J. (2016). Where are the girls in STEM? *Presented at the 6th STS Italia Conference | Sociotechnical Environments*, Trento, Italy.

Paino, M., & Renzulli, L. A. (2013). Digital Dimension of Cultural Capital: The (In)Visible Advantages for Students Who Exhibit Computer Skills. *Sociology of Education*, 86(2), pp. 124–138. https://doi.org/10.1177/0038040712456556.

Peixoto, A., González-González, C. S., Strachan, R., Plaza, P., de los Angeles Martinez-Estévez, M., Blaz & Castro, M. (2018). Diversity and inclusion in engineering education: Looking through the gender question, 2018 *IEEE Global Engineering Education Conference (EDUCON)*, pp. 2071-2075, doi: 10.1109/EDUCON.2018.8363494.

Previo, D. (2017). *Plan de Igualdad de Oportunidades entre Mujeres y Hombres de la UVa 2016-2020.* Universidad de Valladolid.

Robinson, G. & McIlwee, J. (1991). Men, women, and the culture of engineering. *Sociological Quarterly*, 32(3), pp. 403-421.

Salas-Morera, L., Ruiz-Bustos, R., Cejas-Molina, M.A., Olivares-Olmedilla, J.L., García-Hernández, L. & M. Palomo-Romero, J. M. (2021). Understanding why women don't choose engineering degrees. *International Journal of Technology and Design Education*, 31, pp. 325–338. https://doi.org/10.1007/s10798-019-09550-4.

Sweeney, J. (2020). The role of sub-discipline choice in women's enrolment and success within Canadian undergraduate engineering programs. *Proceedings 2020 Canadian Engineering Education Association (CEEA-ACEG20) Conference.* DOI: 10.24908/pceea.vi0.14203.

SWE (2021). SWE Research Fast Facts. Retrieved January 2021 from https://swe.org/wp-content/uploads/2021/10/SWE-Fast-Facts_Oct-2021.pdf

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