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DO WE UNWITTINGLY EXCLUDE STUDENTS? A CASE STUDY TO EVALUATE AN ENGINEERING TEST FOR INCLUSIVITY.

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ABSTRACT

Engineering stereotypes can hinder different groups to identify with and choose for engineering. The stereotypical image, often characterised as male, white and harsh technical oriented, can negatively impact students' perception of engineering as a field to which they can belong.

Recently, PREFER tests were designed to increase students' awareness of the different roles an engineer can take on and of the importance of professional competencies in engineering. Research indicated that the tests were gender-sensitive, meaning that females had other role preferences than males. These results inspired a follow up project to investigate how the tests can be used as instruments to increase attractiveness and retention in engineering.

This paper reports on a study to evaluate whether the PREFER Explore test was designed in an inclusive way. To validate the test with different student groups, a

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survey was distributed among first year engineering students (N=802, October 2022) and final year secondary education pupils in science/math tracks (N=173, March 2023) in Belgium. After completion of the test, participants were asked eight additional questions about their experience with and perception of the test.

Small but significant differences were found in the perception of female and male students, e.g., females identified less with the test and had more difficulties selecting their preference. Students with a migration background indicated that the test strengthened their interest in engineering. The study shows that the perception of different underrepresented groups should be included when validating educational tools if we do not want to unwittingly exclude students.

1 INTRODUCTION

Due to the rapid change in technological innovation, there is a high need to increase the number of engineers in the labour market but also to increase diversity in engineering. To date, the heterogeneous society is not reflected in the engineering population. Consequently, large groups are neglected or disadvantaged by technological innovation. For example, the design of smartphones. Men can comfortably use the device one-handed, but it is harder for people with smaller hands, i.e., women. Voice recognition is not helpful as voice-recognition software is often male-biased (Perez 2019). People of colour have similar problems with face recognition that is tested more with white people. It is clear that a more diverse and intersectional perspective is necessary in technological innovation. The latter is not only beneficial for the end user but also for companies. More diverse teams lead to improved problem solving, increased innovation or more accurate predictions (Hunt et al. 2018).

Engineering stereotypes are one of the factors that can hinder different groups to identify with and choose for engineering. The stereotypical image of engineers, often characterised as male, white and harsh technical oriented, can negatively impact students' perception of engineering as a field that they can belong to or fit in (Bairaktarova and Pilotte 2020; Faulkner 2007; van Veelen, Derks, and Endedijk 2019). Recently, PREFER tests were designed to increase students' awareness of the different roles an engineer can take on and of the importance of professional competencies in engineering (Carthy et al. 2019; 2022). Research indicated that the tests were gender sensitive, meaning that females had other role preferences than men (Carthy et al. 2020). These results inspired us for a follow up project to investigate how the tests can be used as instruments to increase attractiveness and retention in engineering. This paper reports about a further investigation of one of the tests, the PREFER Explore test, on how it is perceived by diverse groups of (future) engineering students.

2 BACKGROUND OF THE PREFER TESTS

The PREFER tests are based on the PREFER framework, an innovative competency based professional roles model that was validated in education and industry (Craps et al. 2021). The framework describes three roles that early career engineers can take on when entering the labour market, independent of discipline: product leadership (focusing on radical innovation and research and development), operational excellence (focusing on product or process optimisation and increasing efficiency) and customer intimacy (focusing on tailored solutions for particular customers). In practice, engineers can operate in a single role, or combine roles. In

close collaboration with industry, 13 expert panels were organised to identify the most important professional (non-technical) competencies required to be successful in these roles. This resulted in a unique reflective instrument that can be used by students to get a grip on the broad field of engineering and to explore what engineering is beyond the engineering stereotypes. A study of Craps (2022) indicated that a more diverse perspective on engineering might influence the female students' confidence that an engineering role is consonant with their interest in a positive way. This leads to making career choices that are more congruent with ones interests and strengths and more job satisfaction.

The PREFER framework provided the foundation for the development of two tests. The PREFER Explore is a personal preference test that aims to inform students about the three professional roles and their preference for one or more roles based on their attitudes towards performing particular tasks (Carthy et al. 2019). The PREFER Match test is a situational judgement test that aims to trigger reflection on students' motivations, strengths and weaknesses by measuring to what extent engineering students are able to judge professional situations (Carthy et al. 2022).

The validation process of the tests involved a sample that was representative for the student population. For example, the PREFER Explore was validated in Belgium and Ireland with 260 engineering students of which 221 were male and 39 were female (15%). However, the validation process was about reliability analysis of the items to identify the preference for a professional role and about clarity of language and instructions. It was not investigated to what extent different groups of students, for example students with other cultural backgrounds who may identify differently with engineering, may experience, or perceive the test in another way than the majority of the current student population.

The PREFER tests were developed for engineering students to increase professional awareness, to trigger reflection on their future self and, as such, to better prepare them for the labour market. However, by broadening the view on engineering and breaking through the stereotypes, the PREFER Explore test has also potential in attracting and recruiting students in engineering education. The test is about discovering future professional roles and related interests and motivation, a helpful instrument in making a study choice. However, this was not yet investigated.

3 RESEARCH QUESTIONS

This study aimed to evaluate the PREFER Explore test for inclusivity. The study was conducted in Belgium, where there is a underrepresentation of female students and students with a migration background in engineering education (Craps et al. 2022). In this study, the following research questions were investigated:

- Do first year bachelor female students have a significant different perception on the PREFER Explore test than male students?
- Do first year bachelor students with a migration background have a significant different perception on the PREFER Explore test than students without a migration background?

In order to use the PREFER Explore test as a recruitment tool in secondary education, the research questions were also investigated with a group of final year secondary school pupils.

4 METHODOLOGY

4.1 Participants

A first survey was distributed in October 2022 among first year engineering students in KU Leuven, Belgium (N=802) during one of their classes. A second online survey was conducted in March 2023 with final year pupils in science or math tracks across 10 secondary education schools (N=172). The pupils completed the survey in class or during a free moment. Participants were informed that participation was voluntary, and that data was analysed anonymously. Ethical approval was obtained from KU Leuven Ethics and Privacy Committee (G-2022-5592-R3).

Table 1 shows the distribution of the sample over sex and migration background. For higher education, the demographical data was provided by the university's database. For secondary education, additional questions were included in the survey. Sex was measured by the sex on someone's passport or their self reported sex. In Belgium, it is possible to change the registered sex on the passport from the age of 16.

Following university guidelines, respondents are considered to have a migration background when they themselves, one of their parents or at least two grandparents, were not born with a Western-European nationality².

Table 1. Descriptive of the participants

	Final year secondary education	First year engineering students (higher education)
Males	81	600
Females	91	202
No migration background	154	726
Migration background	18	76
Total	172	802

4.2 Survey

Students filled in the ten item PREFER Explore test. Per item, three possible options were presented. These options must be ranked from most preferred to least preferred. The test was used for several years with engineering students in different years at the university and abroad. Based on user feedback, little adjustments were made to six items in order to be attractive for different groups and to increase understanding for pupils who are less familiar with engineering. For example, when talking about consultants, a brief definition of consultant was included. Some wordings were adjusted to increase more gender sensitive wordings (The European Institute for Gender Equality 2019; Stroi 2019). *Table 2* shows an example where a rewording appealed to more communal (female) wording. Due to the limitation of the length of this paper, a complete list of the items is available on request.

After completion of the PREFER Explore test, students received eight questions that evaluated how the participants could identify with the cases presented in the PREFER Explore test (see *Table 3*). Participants were requested to indicate their level of agreement on a four-point Likert scale.

² List of Western-European nationalities used by the university: British, Danish, German, Finnish, French, Irish, Icelandic, Liechtenstein, Luxembourg, Dutch, Norwegian, Austrian, Swedish, and Swiss nationality

Table 2. Example of a test item adapted for inclusive language.

Original item	Item adapted for inclusive language
You participate in an event that is aimed at <u>stimulating knowledge sharing in your professional area</u> . You can choose between different kinds of sessions. What sessions would you prefer the least and the most?	You participate in an event known in your field as the event to <u>exchange knowledge and experiences with engineers and other partners</u> . You can choose between different kinds of sessions. What sessions would you prefer the most and the least?

Table 3. Questionnaire to investigate perception of PREFER Explore test

The following statements refer to the cases where you indicated your preference. Please indicate your level of agreement (disagree, rather disagree, rather agree, agree)
Q1 I think the cases described in the questions are interesting.
Q2 I think the cases that were described are realistic situations.
Q3 I enjoyed filling in the questions describing cases where engineers can end up.
Q4 I could empathise with the situations (future) engineers can find themselves in.
Q5 I found it difficult to select the most or least preferred option.
Q6 I could not link the cases to my perception of engineering.
Q7 The cases included words or terminology that I do not entirely understand.
Q8 Reading the cases have strengthened my interest in becoming an engineer.

4.3 Analysis

First, the role preference of students was calculated following the guidelines of Pinxten et al. (2020). A scoring key of +1 was used when an option was selected as most preferred, -1 when an option was selected as least preferred and 0 when the option was selected as neutral (middle answer in the ranking of the options). This resulted in a score per role that varies between -10 and +10. Second, data of the questions Q5, Q6 and Q7 (Table 3) were reversed because the questions were negatively phrased. They were analysed in R using the Wilcoxon test to identify significant differences.

5 RESULTS

5.1 Role preferences

Similar trends in role preference were found with first year engineering students in higher education (HE) and final year pupils secondary education (SE) with a mere preference for the innovative role and less preference for the customer-oriented role. As shown in Fig. 1, female students in both HE ($M=-1.99$, $SD=4.00$) and SE ($M=-1.20$, $SD=3.60$) had significantly more interest in the customer intimacy role than their male peers (HE: $M=-2.94$, $SD=3.35$, $p<0.01$; SE: $M=-2.67$, $SD=4.09$, $p<0.05$). In HE, a significant difference ($p<0.01$) was also observed for the operational excellence role focusing on process optimization with female students ($M=0.54$, $SD=2.81$) having less preference than male students ($M=1.16$, $SD=2.79$). However, the significant differences in preferences were found with small effect sizes (r between 0.9 and 0.18).

Fig. 2 shows the results for students by background. In HE, first, a small significant difference was found for the innovative role: students with a migration background ($M=0.91$, $SD=3.36$) have less interest than their peers with no migration background ($M=1.77$, $SD=3.03$) ($r=0.08$, $p<0.05$). Second, these students ($M=-1.66$, $SD=3.78$) have slightly more interest in a customer intimacy role than the students with no migration background ($M=-2.81$, $SD=3.50$) ($r=0.09$, $p<0.01$).

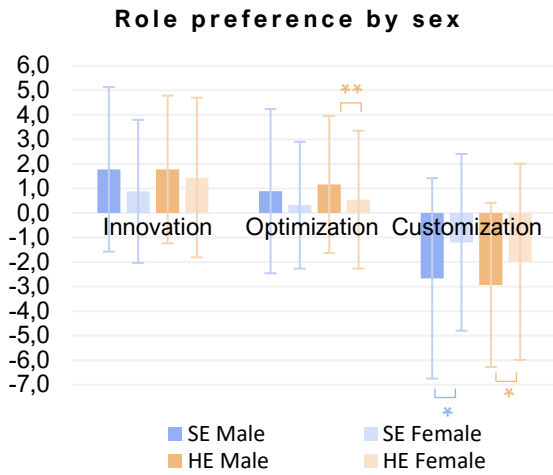


Fig. 1. Role preference of engineering students at university (HE) and final year pupils secondary education (SE) by sex (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$)

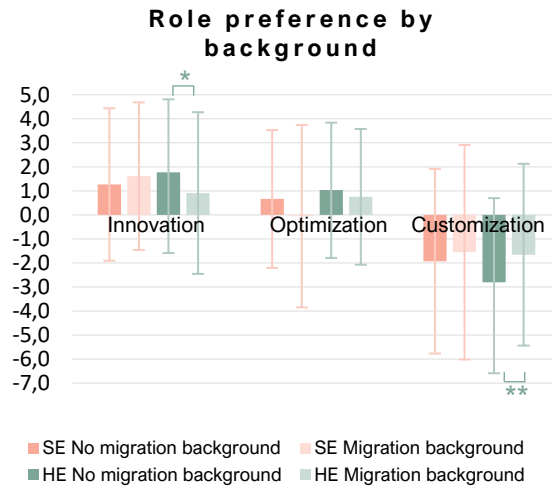


Fig. 2. Role preference of engineering students at university (HE) and final year pupils secondary education (SE) by background (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$)

5.2 Differences in first year engineering students

The questions about how students perceived the PREFER Explore test scored above average for the different groups (Fig. 3). No differences were found in regard to how the different students groups liked the test, found the cases interesting or realistically described.

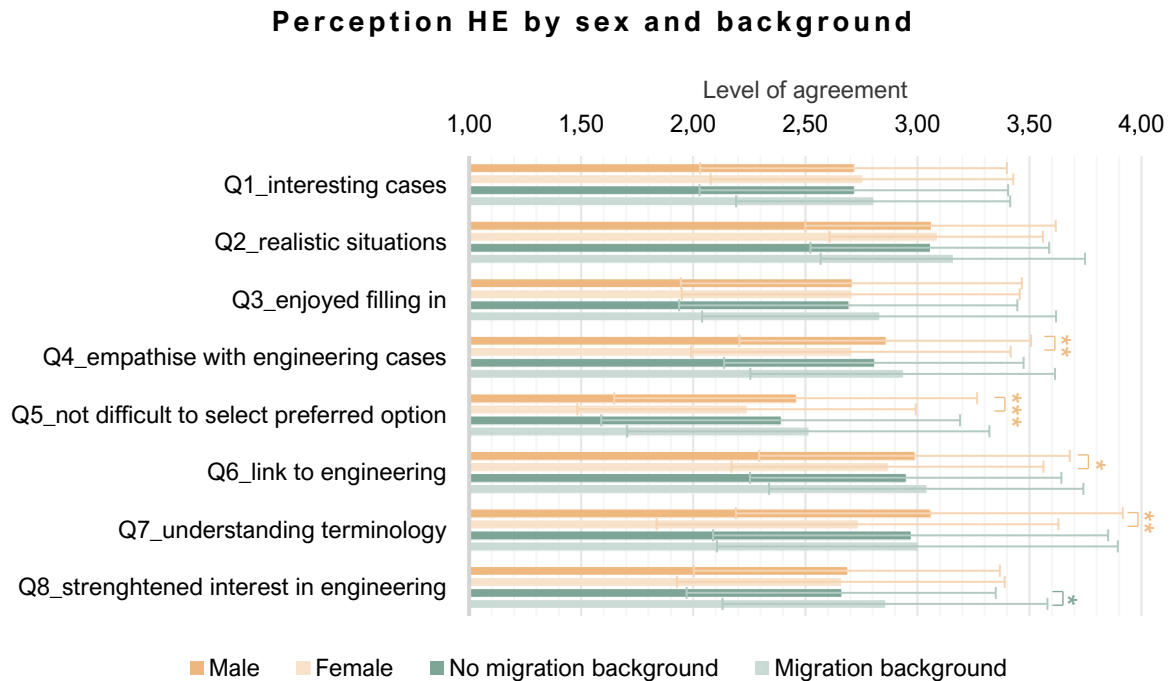


Fig. 3. Perception of the PREFER Explore test of first year engineering students (HE) by sex and background (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$)

However, female students ($M=2.7$, $SD=0.71$) could empathise significantly less with the cases than the male students ($M=2.86$, $SD=0.65$) ($p < 0.01$). Also, they could link the cases less to their perception of engineering ($M=2.87$, $SD=0.70$) than male

students ($M=2.99$, $SD=0.69$) ($p<0.05$), had more difficulties in understanding the words and terminology in the items ($M=2.73$, $SD=0.90$) than male students ($M=3.05$, $SD=0.86$) ($p<0.001$) and in selecting their preferred option ($M=2.24$, $SD=0.76$) compared to male students ($M=2.46$, $SD=0.81$) ($p<0.05$). However, the significant differences were small (effect size r between 0.08 and 0.16).

Regarding background, a small difference was observed for students in regard to the impact of the test on interest ($r=0.08$, $p<0.05$). Students with a migration background indicated that filling in the cases had strengthened their interest in becoming an engineer ($M=2.86$, $SD=0.72$) more compared to students with no migration background ($M=2.66$, $SD=0.69$).

5.3 Differences in final year secondary education pupils

For secondary education, no significant differences were found between students with or without migration background (Fig. 4).

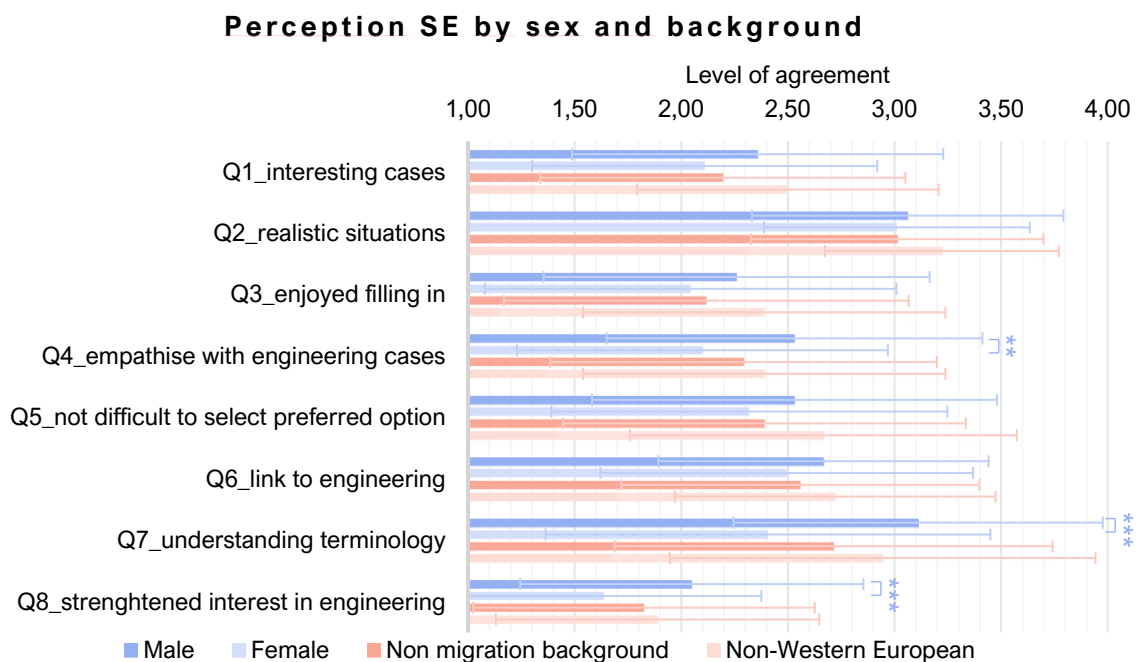


Fig. 4. Perception of the PREFER Explore test of final year pupils secondary education (SE) by sex and background (* $p<0.05$; ** $p<0.01$; *** $p<0.001$)

Similar to first year engineering students, the female pupils ($M=2.10$, $SD=0.87$) could significantly less empathise with the situations (future) engineers can find themselves in than their male peers ($M=2.53$, $SD=0.88$) ($r=0.23$, $p<0.01$). Also, they had more difficulties in understanding the wordings and terminology ($M=2.41$, $SD=1.04$) than male pupils ($M=3.11$, $SD=0.87$) ($r=0.33$, $p<0.001$). The PREFER Explore test helped male pupils ($M=2.05$, $SD=0.80$) more in strengthening their interest in engineering than it helped female pupils ($M=1.64$, $SD=0.74$) ($r=0.26$, $p<0.001$).

6 DISCUSSION

It is important to recognise different identities and perspectives in order to increase the feeling of belonging in engineering for different groups and enhance diversity in engineering. This study investigated whether the PREFER Explore test can be used

as an inclusive tool for diverse student groups by examining differences in perception between male and female first year engineering students, and between students without and with a non-Western European background in Belgium. It also examined the differences with a group of final year secondary education pupils in science/math tracks that prepare for engineering programmes at university.

In line with earlier studies (Carthy et al. 2022; Craps 2022), the PREFER Explore test seems to be sensitive for gender. This study shows the test seems also sensitive for migration background. For example, like female students and pupils, students with a migration background had slightly more preference for a customer intimacy role. Earlier research with engineering students showed that students were least familiar with the customer oriented role (Craps et al. 2019). When pupils are not aware that this role is an engineering role required in the labour market, they will less easily identify with engineering. This can negatively impact their choice to study engineering or to remain in the engineering programme. The communal and social aspect of engineering, that is more likely valued by women (Cech 2015; Bairaktarova and Pilotte 2020), is reflected most easily in the customer intimacy role that requires essential professional competencies such as clear communication (with people having non technical background), capacity for empathy, etc. (Craps et al. 2021). Therefore, it is important to make more explicit for (future) engineering students that engineer can take on diverse roles and what those roles require (Naukkarinen and Bairoh 2021).

When analysing the perceptions of the PREFER test with first year engineering students, it was observed that female students had more difficulties with empathising with the cases, linking the cases to their perception of engineering and with the wording and terminology. A perhaps logical consequence is that they found it more difficult to select their preferred options. Follow up research is required to better understand these small but significant differences. A possible explanation can be that words that are linked to engineering are, in general, more male biased, and, consequently, the items are still too male biased (The European Institute for Gender Equality 2019). Another explanation for the lower scores can be that women tend to underestimate their ability beliefs and in their self-confidence, in particular in male dominated fields (Bordalo et al. 2016; Perez-Felkner, Nix, and Thomas 2017).

An interesting finding is that students with a migration background indicated that the test had helped to strengthen their interest in engineering. In Belgium, one of the hurdles for this underrepresented group are a lower retention rate in the engineering programme. This finding strengthens the authors' belief that the PREFER tools can be useful instruments to strengthen the motivation and retention of this group. A next step in this research project will be the development of interventions for first year engineering students to motivate all students, and students with a migration background in particular, by explicitly work on their future engineering identity and the feeling of belonging in engineering (Craps et al. 2022).

The findings with secondary education pupils show that the PREFER Explore test is not yet ready as a recruitment tool that helps a more diverse group of pupils to choose to study engineering. The test helped to strengthen the interest of male students more compared to females, but the overall score was rather low. It should be noted that in Belgium, there is an open admission and a free choice to study any programme in higher education. This means that, although the participants were following science/math tracks that prepare for engineering, they can also opt for a

study in humanities. Linking these findings to their interest in STEM would give more accurate results. Also, it would be interesting to include an intersectional approach of gender and migration background. In this study, a better understanding of the perception of females with a migration background was not possible due to the low numbers in our sample.

7 SUMMARY

Increasing diversity in engineering has never been more important. This study investigated how different groups perceived the PREFER Explore test: a personal preference test aiming to broaden the view on engineering and exploring one's motivations in engineering. The test was found to be sensitive for gender and migration background. Small significant differences were observed for female students who related less with the test, found it more difficult to understand the wordings and terminology or to indicate their preferences. More research is required to understand these differences. With regard to migration background no differences in perception were found, except for students with a migration background who indicated more often that the test strengthened their interest in engineering. These results are promising when developing interventions to increase motivation and retention in engineering. The study showed that focusing on the perception of different (underrepresented) groups is needed in educational development and research if we strive to increase diversity in engineering. By validating our tools and interventions with samples that represent the current (mainly white and male) students groups, we may unwittingly exclude (underrepresented) students.

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