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A Look Inside The Engineering Students' Backpack: Differences In Engineering Capital According To Gender Or Migration Background.

Mieke CANNAERTS
Ku Leuven, Belgium, mieke.cannaerts@kuleuven.be

Sofie CRAPS
Ku Leuven, Belgium, sofie.craps@kuleuven.be

Veerle DRAULANS
Ku Leuven, Belgium, veerle.draulans@kuleuven.be

See next page for additional authors

Authors

Mieke CANNAERTS, Sofie CRAPS, Veerle DRAULANS, and Greet LANGIE

A LOOK INSIDE THE ENGINEERING STUDENTS' BACKPACK.

DIFFERENCES IN ENGINEERING CAPITAL ACCORDING TO GENDER OR MIGRATION BACKGROUND.

M. Cannaerts [1]
Leuven Engineering & Science Education Centre (LESEC), Faculty of Engineering Technology, ETHER Group, Campus De Nayer, KU Leuven, Belgium ORCID 0000-0001-8167-205X

S. Craps
Leuven Engineering & Science Education Centre (LESEC), Faculty of Engineering Technology, ETHER Group, Campus Group T, KU Leuven, Belgium
ORCID 0000-0003-2790-2218

V. Draulans
Centre for Sociological Research Ceso, KU Leuven, Belgium
ORCID 0000-0001-9590-5870

G. Langie
Leuven Engineering & Science Education Centre (LESEC), Faculty of Engineering Technology, ETHER Group, Campus De Nayer, KU Leuven, Belgium
ORCID 0000-0002-9061-6727

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[1] Corresponding Author:
M. Cannaerts
mieke.cannaerts@kuleuven.be

ABSTRACT

Every student has a unique combination of experiences, resources and social networks related to engineering, called ‘engineering capital’, derived from Archer’s concept of ‘science capital’. The engineering capital gathered throughout life creates a backpack that impacts someone’s aspirations to study engineering, as well as the performance and persistence in the programme itself.

Engineering technology is one of the most homogeneous fields within the STEM domain, being mostly white and male. To stimulate a more diverse engineering technology field, this research paper investigates the relationship between the level of engineering capital and gender or migration background, as well as the influence of engineering capital on aspiration and performance within the engineering technology field.

Through an online survey, last-year secondary education pupils in math/science tracks (N = 490, March 2023), and first-year engineering technology students (N =391, October 2022) in Belgium were asked about their engineering capital, and engineering aspiration (pupils) or performance (students). Results disclose little difference in engineering capital, engineering aspiration, or engineering performance for students with a migration background. However, female pupils appear to have less engineering capital than male pupils, and in need of more engineering capital to gain an interest in engineering technology compared to male pupils. Once women start the engineering technology program, engineering capital does not influence female students’ performance differently than male students. It is possible that only those with a heavy backpack of engineering capital find their way to the program. That is why it is important that educators stimulate students’ engineering capital.

1. INTRODUCTION

Two of the challenges faced by the engineering field are a shortage of engineers and a lack of diversity among engineers. Tackling the diversity problem can help solve the shortage of engineers by tapping into a bigger pool of talent. Diversity is not only important to attain more qualified engineers and prevent a loss of talent, it also enhances the work quality, enabling the industry to thrive. The more diverse the field, the more diverse the perspective, experiences and knowledge that are represented, which makes it easier to cater to the needs of the whole population (Page 2019).

In many countries, we see a recurrent pattern of the engineering field lacking women and people from non-dominant cultural background (Charles and Bradley 2009). Understanding why STEM-interested students do not enter the engineering field and why some groups struggle more than others during engineering education programs is essential to promote more diversity in the profession.

The concept of ‘*science capital’* is one element to understanding this problem (Louise Archer et al. 2015; Moote et al. 2021). Children and adolescents who have access to a strong science capital, through science support, knowledge, and attitudes, have a higher chance of achieving a science degree (Louise Archer et al. 2012; Aschbacher, Li, and Roth 2010). Science capital is often intertwined with other forms of capital, such as social or cultural capital. As a result, it can perpetuate the reproduction of privilege, or contribute to vulnerability (Moote et al. 2021).

This paper shifts the focus from science to engineering, by seeking an answer to the following research questions: RQ1 ‘does the level of engineering capital varies according to gender or migration background?’; RQ2a ‘does the level of engineering capital influence aspiration and performance within the engineering field?’; And RQ2b ‘does the relationship between engineering capital and engineering aspiration/performance change according to gender or migration background?’.

2. THEORETICAL FRAMEWORK: THE CONCEPT OF ‘CAPITAL’

2.1. Cultural and Social Capital

Bourdieu expanded the theory on social reproduction beyond the economic factor by including other forms of capital. He argued that social, cultural, and symbolic capital were vital to the transfer of societal power from generation to generation (Bourdieu 1986). In this paper we will focus on the first two: (1) *Cultural capital* refers to subtle, unwritten rules, values and knowledge structuring the social world. Access to cultural capital comes from both material (e.g., books, music instruments) and immaterial things (e.g., learning a new language, visiting a museum). (2) *Social capital* represents the network that surrounds someone, such as family, teachers, or friendships (Bourdieu 1986).

How capital is distributed and valued is determined within a certain social context, which Bourdieu called *field*. It is the social space in which an individual acquires capital and develops a habitus (Bourdieu 1986). *The habitus* can be seen as embodied capital that is shaped by socialization and influenced by individual characteristics like gender or ethnicity (Nash 1990).

A unique set of experiences shape how individuals interpret the world around them and outlines what seems possible and/or desirable, guiding behaviour, actions, and choices (Bourdieu 1986; Nash 1990), e.g., an educational trajectory. Bourdieu defines educational success in relation to the cultural capital that was previously invested by the family, i.e., social capital. Of course not only the level of capital is important, but also the precise content. Educational systems are often based on the dominant culture in society, which means that capital gained at home through conversations and experiences is perpetuated in the classroom. Children who’s capital and habitus are in line with the dominant culture in society will be viewed as smarter and more accomplished by others, and will navigate and flourish more easily in that society. While children who embodied a different habitus compared to the dominant culture will have more trouble fitting in (Nash 1990; Bourdieu 1986; Martin, Simmons, and Yu 2013).

2.2. ScieNce Capital

By looking at science education with a Bordieusian lens, Archer et al. (2012) learned how science-related capital, i.e., *science capital*, influences science aspiration, participation and performance. Science capital represents the backpack that people carry, filled with both social and cultural capital related to science (Louise Archer et al. 2015). Having access to parents’ knowledge, encouragement from teachers, and own experiences with science can help to prevent struggling in school, and develop a strong science identity, which will improve the ability to persist, even when struggling (Gonsalves et al. 2021).

To measure science capital, Archer et al. (2015) focused on three theoretical aspects, namely: habitus (their science attitudes), social capital (parents, teachers, conversations, etc.), and cultural capital (media consumptions, science-related activities, etc.).

2.2.1. Engineering capital

While having an extensive impact on society, engineering is one of the most homogenous fields across several countries (Charles and Bradley 2009). To improve the engineering aspiration and/or persistence of a more diverse group, we need to understand what influences engineering attitudes.

Research from Moote et al. (2020) showed that science capital was correlated with engineering attitudes (0.423), however, not as much as with science attitudes (0.779). To gain a better understanding of capital that is more focused on engineering, the focus is shirted from science capital towards engineering capital, by altering the questions about ‘science’ to ‘STEM’ or ‘engineering’, depending on the context.

2.3. The reproduction of social privilege

If having more science capital can make it easier to earn a degree in a science field, it is prevalent that those who have less science capital, will have more difficulty to get there. When looking at the often homogenous groups of STEM students being from a middle or high class family, often white, and male (depending on the field), we can wonder why this homogeneity prevails (Moote et al. 2021).

Students from a long-term educated family, especially in a science field, have more chance to build science capital, and are therefore often overrepresented in science education (Dorie et al. 2014). People with a migration background more often belong to a shorter term educated families, resulting in lower level of science capital that is in line with the dominant culture. Even when they have a lot of interest and talent for science, they will be less likely to see themselves as a scientist, let alone choose or persist in a scientific domain (DeWitt et al. 2011; Aschbacher, Li, and Roth 2010; Gonsalves et al. 2021).

The same goes for women, who less frequently pursue a science degree compared to men (Moote et al. 2021). In Western society, science is associated with cleverness and masculinity (Louise Archer et al. 2020). From the age of 6, girls already perceive their own intelligence lower than the intelligence of boys, leading them to pursue less activities connected with cleverness (Bian, Leslie, and Cimpian 2017), science or engineering being one of these. Not only do they underestimate their own intelligence, the general bias of science and STEM being for boys, lead to more encouragement for boys from their surroundings and results in less science capitals for girls. The girls who do find their way to STEM often need a stronger conviction, or habitus, wanting to study science and go against the grain of what society (unconsciously) expects from them (Louise Archer et al. 2020; Aschbacher, Li, and Roth 2010).

When children or adolescents do not have access to science capital through their parents or resources at home, school becomes an important source of science capital. Educators in secondary school, but also at the university, can give guidance, support, and encouragement when needed (Martin, Simmons, and Yu 2013). When it comes to engineering, it is difficult to know what skills or preparations are needed for a degree in engineering, especially when parents are not familiar with what engineering is, or even with the university system. Educators play a crucial role in guiding students towards their desired path (Dorie et al. 2014; Martin, Simmons, and Yu 2013).

3. METHODOLOGY

3.1. Participants

This study is based on two surveys. The first was conducted in October 2022 (N=343 after cleaning; 36 female; 20 with a migration background) among first-time engineering technology students at KU Leuven, Belgium. First-time students are first-year students who enrol right after completing high school. The students who wanted to participate had the opportunity to voluntarily fill in the survey during one of their classes. Later in this paper we will refer to the results from the bachelor of engineering technology with 'ET'.

The second survey was conducted in March 2023 (N=443 after cleaning, 203 female; 58 with a migration background) with last-year pupils in science or math tracks, across ten secondary education schools. The pupils voluntarily completed the survey during class, or during a free moment, except for two schools where the pupils could conduct the survey online at home. Later in this paper we will refer to the results from secondary education with 'SE'.

3.2. Analysis

After conducting a descriptive analysis of the data using boxplots or comparison of means, a multiple regression analysis was performed. When comparing means, in the form of a table or boxplot, the Wilcoxon test with Holm adjusted p-value was used to identify significant differences. The aim of the regression analysis is to examine the relationship between sex and migration background as independent variables, engineering technology aspiration (SE) and performance (ET) as dependent variables, and engineering capital as both dependent and independent variable. Section 3.3 explains how these variables are defined and measured. Additional independent variables are added to the model as control variables depending on the target group, namely: secondary education study field (SE), parents education level (SE & ET), and language spoken at home (ET). However, we will not focus on the control variables in this paper.

When talking about a determination coefficient, the given number will always represent the adjusted R^2. Due to lack of space, the full regression tables are not included in the paper, but are available upon request.

3.3. Concepts:

3.3.1. Independent variables

The university database was used to enrich the ET dataset with demographical variables. The same logic is applied to question the SE pupils about their demographical background. A short explanation per variable is found below.

Gender/Sex: Measured by the sex on someone's passport (ET) or their self-reported sex (SE). This means that we do not have any data on someone's gender identity, although it must be noted that, in Belgium, it is possible to change the registered sex from the age of 16.

The term 'gender' is used when referring to the literature and research questions, since this is more commonly used.

Migration background (MB): Following university guidelines, respondents are considered to have a migration background when they themselves, one of their parents or at least two grandparents, are not born in with a Western-European nationality[2]

Engineering capital: Question from Archer's et al. (2015) scale to measure the concept of science capital were translated to Dutch and altered to focus more on STEM of engineering. The scale consists of preferences, practices, and social connections, related to STEM or engineering. Every question was weighted according

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

to their theoretical significance (e.g., having a parent as an engineering has more impact than having an aunt as an engineer) and given a score ranging from 1 to 5 (Moote et al. 2020). The total sum was rescaled to a scale of 0 to 60.

Control variables: Education level of the parents; form of education; field of study in secondary education (only for SE); language spoken at home (only for TE).

3.3.2. Dependent variables

Engineering aspiration: Last year pupils were asked about their interest in studying engineering technology on a 5-point Likert scale.

Engineering performance: The students Grade Point Average (GPA), measured in percentages (0-100), is used to address the student's performance. In this paper, the GPA of January 2023 were analysed.

4. RESULTS: A LOOK INSIDE THE (FUTURE) ENGINEERING STUDENTS BACKPACK

4.1. Distribution of engineering capital

4.1.1. Boxplots

Secondary education (SE)

The boxplots in figures 3 and 4 show the engineering capital in SE and gives an insight in how engineering capital is distributed according to sex and MB. In figure 3 we see that female pupils have a significantly lower engineering capital compared to male pupils. The minimum and maximum for the female pupils is also lower than this of the male pupils.

For MB, the median of the category non-MB is slightly lower than the category MB, however, the Wilcox test does not show any significant differences.

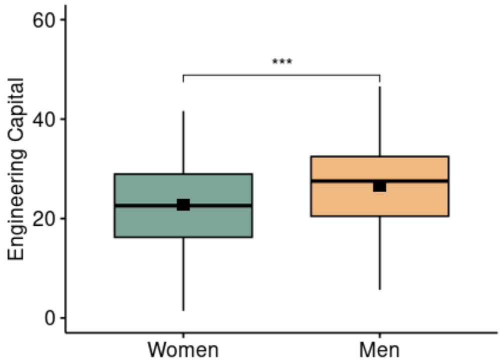

Figure 3: Boxplot of engineering capital in secondary education according to sex

**** p<.001*

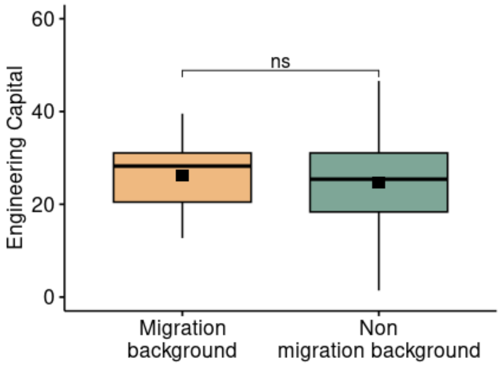

Figure 4: Boxplot of engineering capital secondary education according to migration background

Engineering Technology (ET)

The results of the ET students indicate that male students have a slightly higher median and more variance in their group than female students. Students without a MB also score higher compared to students with a MB. However, both comparisons are not significant.

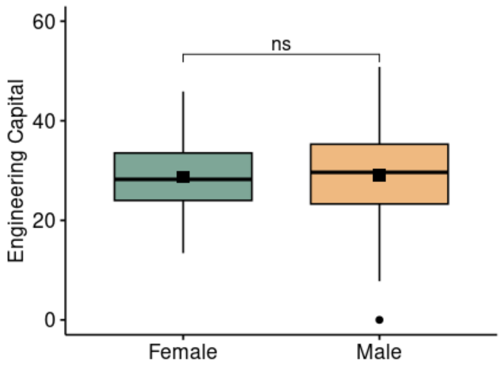

Figure 5: Boxplot of engineering capital in Engineering Technology according to sex

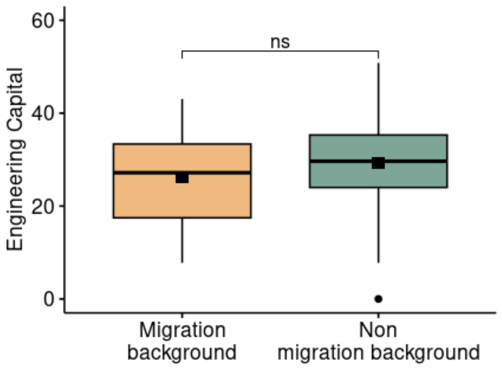

Figure 6: Boxplot of engineering capital in Engineering Technology according to migration background

4.1.2. Linear regression analysis

Secondary education (SE)

The regression models show the impact of the demographic variables on the engineering capital. The results indicate that female pupils have a significantly lower level of engineering capital compared to male pupils by 3.01 points, or 2.92 when controlling for the other variables. Pupils with a MB, however, did not show any significant impact on the engineering capital compared to pupil without a MB.

It is important to note that when looking at the determination coefficient, the model including sex and MB has an explanation value of 2.7%, which is mostly due to sex. The model with all the control variable has an explanation value of 9.7%, hence, pupil's study field and the education level of their parents probably have a bigger influence on their engineering capital.

Engineering Technology (ET)

When analysing results for ET, no significant effects are observed. Even when adding all control variables, the determination coefficient (adj. R^2=.009) shows that the independent variables added to the models are not explaining the variance in the level of engineering capital effectively.

4.2. Engineering aspirations in SE

4.2.1. Comparison of means

Since interest in ET is measured using one scale, we analyse mean scores instead of a boxplot. Male pupils appear to have a significant higher interest in engineering technology compared to female pupils. Pupils with a MB have a slightly higher interest in engineering technology compared to pupils without a MB.

Table 1: Interest in engineering technology means, st.dev., and Wilcox test results

SE		*Mean - interest Engineering Technology*	*Standard deviation*
Sex	Female	1.86***	0.98
	Male	2.98***	1.29
Migration background	No MB	2.41*	1.29
	MB	2.84*	1.25

p<0.05*; p<0.01**; p<0.001***

4.2.2. Linear regression analysis

The linear regression models show a significant effect for female pupils, where they have a lower interest in engineering technology than male pupils. This effect is weakened by adding engineering capital to the model (from β = -1.13; to β = -0.96).

Engineering capital also has a significant effect on the interest in engineering technology. For every point increase in the level of engineering capital, the interest in engineering technology increases with 0.07. No significant result was observed for students with a MB.

Interestingly, a significant interaction effect was observed between engineering capital and sex (β = -0.03), meaning that their combined effects are greater than their sum of parts. The main effect for sex did not remain significant after adding the interaction effect, while the main effect for engineering capital did remain significant (β = 0.07). This indicates that sex moderates the relationship between engineering capital and engineering aspiration.

The determination coefficient for the model looking at sex (adj. R^2 = 0.19) or engineering capital (β = 0.18) have a variance explanation of almost 20%. The last model where the control variables have been included has a variance explanation of 30%. When adding the interaction effect this is increased to 31%, indicating a slightly larger proportion of the variance in engineering aspiration being explained.

4.3. Engineering performance in ET

4.3.1. Boxplots

For engineering performances, male and female students performed similarly, while students without a MB score higher compared to students with a MB. However, there are no significant differences.

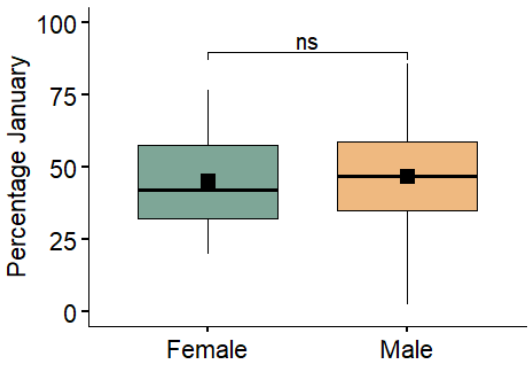

Figure 7: Boxplot of engineering performance in Engineering Technology according to sex

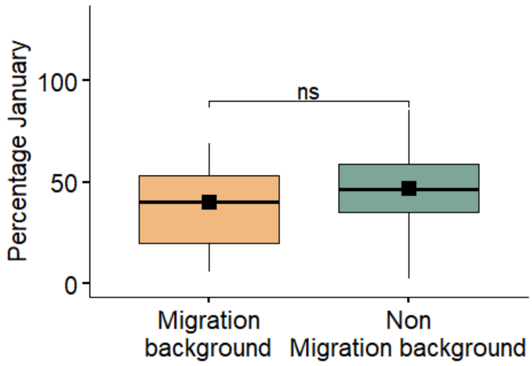

Figure 8: Boxplot of engineering performance in Engineering Technology according to MB

4.3.2. Linear regression analysis

The linear regression models of the GPA of engineering technology students do not show any significant effects for sex or MB on their GPA. However, engineering capital does have a significant effect. For every point increase in engineering capital, there is an increase of 0.43 on the GPA. This effect stays similarly when controlling for the other variables. Nevertheless, the variables added in the model seem inadequate to predict engineering performance, since the variance explanation is only 1.9%.

5. DISCUSSION AND CONCLUSION

This paper sought to investigate the relationship between engineering capital and sex or migration background, as well as between engineering capital and engineering technology aspiration in secondary education (SE) or performance in engineering technology (ET).

To answer the first research question '*does the level of engineering capital varies according to gender or migration background?*', it is important to make a distinction between secondary education and higher education. While there were no significant results for ET students, results for pupils in SE showed a difference in engineering capital based on sex, where female pupils had a lower engineering capital compared to male pupils. However, the regression model showed that sex explained only 4,4% of the variance in pupils engineering capital.

For the second research questions '*does the level of engineering capital influence aspiration and performance within the engineering field?'* And *'does the relationship between engineering capital and engineering aspiration/performance change according to gender or migration background?*' we can conclude that engineering capital does influence both engineering aspiration and performance, but that it is not always moderated by sex or migration background. The level of engineering capital has a significant positive effect on engineering performance, but this effect is not moderated by sex or migration background. Engineering aspiration is also positively and significantly influenced by engineering capital. However, an interaction effect showed that this relationship is moderated by sex, where female pupils need more engineering capital compared to male pupils to develop an interest in engineering capital.

We can conclude that female pupils have a lower engineering capital compared to male pupils and need more to gain engineering aspiration. This helps to explain that only a small group of women chooses to study engineering technology. Possibly due to the fact that only women with enough engineering capital choose to study engineering technology (see RQ1), there are no differences in performance between men and women once they enter the program. Unfortunately, we did not find enough significant results for the pupils and students with a migration background to form any conclusions.

Following the literature, a stronger connection between engineering capital and engineering performance was expected. Literature shows that engineering, or science, capital increases the chance of success in engineering education programs (Zhang 2021; Moote et al. 2021), which was only slightly visible in this study. For engineering aspiration, a clear connection with engineering capital was observed, including a moderation of the respondents sex This is in line with the literature that says that women need a stronger conviction to study engineering than men (Aschbacher, Li, and Roth 2010; L. Archer et al. 2020).

These conclusions need to be considered with precaution, due to the small numbers in our target groups. A difficulty that pops up when doing quantitative research on underrepresented groups. It would be opportune to address this matter further in qualitative research to get a better understanding of how engineering capital influences students. This approach could also give room for a focus on intersectionality between several characteristics, such as women with a migration background, for which the groups were too small in this study.

When wanting to improve the diversity in engineering programs, it is important to also focus on the pupils that were not blessed with a heavy backpack full of engineering capital and to make sure to support them and stimulate their engineering capital once they do find their way to the engineering program. Educators can take up the role of improving science capital for a diverse group of students in the form of teaching, museum visits, but also support and encouragement.

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