EXPLORING THE ROLE OF NATIONAL EDUCATION SYSTEM ON PATHWAYS INTO ENGINEERING: A COMPARITIVE STUDY (WORK IN PROGRESS)

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ABSTRACT

Reported shortages within the engineering workforce have resulted in significant efforts to promote engineering facilitating education pathways across Europe, particularly to those underrepresented within the sector. Such work has become

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significant in recent decades because of global demographic changes which are likely to have increasing impact upon higher education (HE) systems. Given contextual differences between countries, understanding opportunities and barriers to recruitment of students requires a comparative approach which considers differences in education systems and admissions processes. At this initial pilot phase of this exploratory study, we have focused on understanding national education systems and admissions practices in three European countries, namely Belgium (Flanders), Czechia, and the UK. The analysis of the data provided is guided by research questions focused on 1.) the main education paths into an engineering career and any remedial routes, 2.) the qualifications and prerequisites required to study engineering within HE, and 3.) details of any exposure students have to engineering, both within and outside the curriculum, prior to university. Findings from this work in progress study will be used to inform design of large-scale research project to identify practices across SEFI.

1 INTRODUCTION

Europe faces demographic issues associated with an ageing population and low birth rates which influence the population at working age, and thus economic growth (United Nations, 2022). At present, impact on higher education (HE) systems is limited. However, the (at least) 18-year gap between birth and university enrolment means this is likely to change. Universities may take several approaches to such situations, for example focus efforts on widening access and participation.

Such challenges are particularly pertinent within engineering, for which attraction and retention of students has long been an issue. The 2023 annual review of the 'Employment and Social Developments in Europe' report identified engineering as an occupation/sector expected to face shortages in labour (European Commission, 2023). Furthermore, the report describes the persistent labour shortages in sectors with low percentages of female[1] workers, directly attributing this to differences in study fields of qualifications (particularly at tertiary level) held by women and men (European Commission, 2023). In keeping with this, the European Strategy for Universities articulated a commitment to strengthening women's and girls' participation in STEM (European Commission, 2022).

At such times, the role of admission processes become significant. Orr et al. (2017), consider how admissions systems are understood in different social, cultural, political, and economic contexts (such as those found across Europe). Within this perspective, they describe three ways in which schools influence students' access to HE: by assigning grades; by streaming by academic ability; and by providing careers information, and guidance. With respect to higher education institutes (HEIs), they

[1] Whilst the report cited primarily focuses on the gender employment gap, the authors acknowledge the underrepresentation of students with several characteristics within engineering, for example by disability, age, sexual orientation, ethnicity (e.g., see Mejia and Martin, 2023)

highlight differences in autonomy over selection processes, and assessment of academic ability. Finally, they describe the complexity of student decision making.

1.1 Typology of Admissions Systems

Orr et al. (2017), defined a four-field matrix to produce a typology of admission systems based on a comparative study of 36 European countries. Within this, one dimension represents the freedom of HEIs with respect to their ability to set their own criteria to select students. The other dimension focuses on the pathways to HE and streaming within the secondary system (i.e., whether all streams lead to HE).

- Type 1 (selection by schools) includes countries in which HEIs cannot select with additional criteria and where students are placed in various streams where at least one stream does not allow access into HE.
- Type 2 (selection by HEIs) is used for contexts in which all pathways allow access to HE and in which HEIs can typically select with additional criteria.
- Type 3 (least selection) is similar to Type 2, but HEIs have less autonomy to select additional criteria.
- Type 4 (double selection) is the same as Type 2, but at least one of these stream qualifications do not allow access into HE.

They used this typology to examine admission systems in terms of three dimensions: (1) equity dimension (who gets into HE), (2) efficiency dimension (how many complete studies), and (3) effectiveness dimension (final attainment and outcomes). Their analysis revealed differences in unemployment, job mismatches, participation rates, graduation/completion rates across the types of systems, some of which could be linked to selectivity. The research highlights both the relationship that education systems and admissions processes have with recruitment and retention of students, and the way in which systems vary between country. It may therefore be expected engineering students' demographics vary between countries characterised by different education typologies. Table 1 shows typology and student characteristics for the three countries considered in this study.

Table 1: Country typology and engineering student characteristics

Country/ Typology	CZ (Type 2; selection by HEIs)	Flanders, Belgium (Type 3; least selection)	UK (Type 4; Double selection)
Engineering student demographics	58% male, 42% female 85% Czech 15% non-Czech	74% male, 26% female 85% Belgian, 15% non-Belgian	80% male, 20% female 63% UK, 37% non-UK (HESA, 2023)

Understanding the opportunities and barriers with respect to attracting students to engineering within Europe thus requires a comparative approach which considers differences across contexts. As such, this work in progress study aims to improve our understanding of how education systems and HEI admissions practices vary across Europe. Such data will be used to identify trends and patterns across systems and the resultant admissions and retention figures in engineering.

2 METHODOLOGY

At this initial pilot phase, we have focused on three European countries in which the authors of the paper reside, namely Belgium (Flanders), Czechia, and the UK.

In mapping the education systems and admissions processes within Europe, we position ourselves as 'experts' in our own contexts. In the initial stages the authors shared context specific information pertaining to 1.) the primary and secondary education systems and educational pathways to becoming an engineer and 2.) the admissions processes of universities within their context. This process allowed for initial comparison and identification of relevant contextual factors previously omitted. It also provided an opportunity for authors to engage in critical reflection regarding perceptions, enhance understanding and interpretation, and examine the limits of reflexivity. The Flemish context was analysed by two authors independently and compared to decrease the impact of author's own perceptions. The limited disagreements were discussed and resolved.

Data was subsequently combined, with publicly available information allowing for triangulation and ensuring creation of a comprehensive picture. Data analysis was guided by the following research questions (RQs) and Orr et al.'s (2017) typology.

1.) What are the main educational pathways/'remedial routes' into engineering?
2.) What are the qualifications/prerequisites required to study engineering in HE?
3.) Do students have exposure to engineering during secondary education?

The complexity of school education systems, in terms of starting age, grouping of ages, organisation of the school year/week/day, geographical accessibility, admissions systems, funding models, governance and teacher profile, amongst other factors, has led to the development of a variety of different methodologies by which to compare them. For example, one may make use of philosophical, social, historical, quantitative/statistical, descriptive or scientific methods. In this work we focus on the pathways into engineering, with particular focus on routes to studying engineering in HE. In so doing, we make use of Orr et al.'s framework (2017) because of its focus on university admission processes. In doing this we acknowledge inherent limitations of our work which does not include consideration for aspects such as societal and cultural perceptions of HE, and the engineering profession, as well as other factors which impact transitions into engineering.

3 RESULTS

Belgium: Flanders:

In the Flemish system, a certificate of upper secondary education grants unrestricted access to HE (Eurydice, 2024). It can therefore be considered a Type 3 system.

As shown in Figure 1, at 12 years old, pupils start secondary education, the majority in the A stream (84.25%) (Onderwijs Vlaanderen, 2024), a general stream leading to different pathways at 14 years old. The secondary education system in Flanders used to be divided into general, technical, arts and vocational secondary education but, recently, the system was reformed offering three pathways. Tracks in the first

pathway '*transfer*' lead to HE studies, tracks in the second '*vocational*' pathway lead to the labour market, tracks in the third pathway '***double'*** can lead to both HE and labour market. Each pathway consists of different study domains (STEM, Arts and Creation, Language and Culture, Cross-domain, etc.) with more discipline specific study tracks. Students from the cross-domain and STEM domain tracks are attracted to, and best prepared for, engineering. The first important study domain and track choice is at 14 years old, with a more discipline specific track choice at age 16.

Depending on the chosen study track, the weekly hours of mathematics vary. Also, students' experience with engineering varies, ranging from limited or no experience with an integrated STEM subject in the cross-domain tracks, to whole subjects titled 'engineering' available in some of the STEM domain study tracks. Despite the availability of study tracks focussing - to a larger or smaller extend - on technology and engineering, the main recommendation for successful study completion in an academic engineering programme is a prior education with at least four, preferably six, weekly hours of mathematics (Pinxten et al., 2017). Despite open HE access and flexibility for late commitment to study engineering, students' choice for study tracks and domains with few math hours (e.g., languages and arts) decreases the chance to continue in engineering.

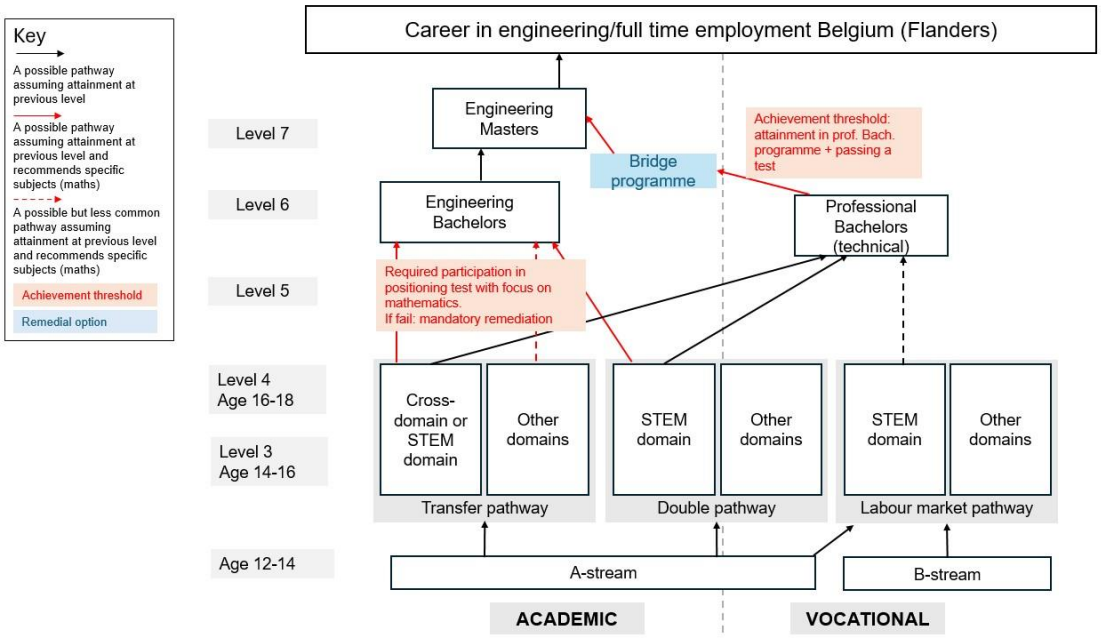

Figure 1: Schematic showing pathways to engineering in Belgium (Flanders)

To emphasize the importance of mathematical mastery, all engineering science and engineering technology HE programmes across Flanders initiated a positioning test in 2013 (Vanderoost, 2014; Hanssens, 2024). Although these tests are perceived as useful for students to assess their level of starting competencies, and for HEIs to identify students-at-risk, the test may also create unrealistic expectations of the engineering programme by creating feelings of high anxiety or overconfidence to start the programme (Hanssens et al., 2023). Students who fail follow a mandatory remedial programme in the first year of HE. The university foresees remedial routes for students obtaining vocational STEM undergraduate degrees in university

colleges. After successful completion of bridge programmes, students who fulfil access requirements have permission to start an academic engineering programme. Although this route into engineering is often presented as attractive by university colleges, the bridge programmes have relatively high dropout rates. The different HEIs in Flanders reorganised these programmes recently and made access criteria stricter and programmes longer (60 to 90 credits). When choosing HE studies, students are often not aware of this.

The title “engineer” is not legally protected. A professional title is only granted to Master graduates of Flemish engineering HE programmes in Engineering Sciences (ir) or Bioscience Engineering (ir), and in (Bio)Engineering Technology (ing).

Czechia

The route to being granted the Ing. (engineer) title is not strictly defined but it mostly involves education in technical fields (with some historical exemptions e.g., economic fields) at master level. The Czech education system (Type 2) includes two main recognised pathways leading to engineering at a HEI (see Figure 2): academic and vocational (CNAIER, 2023). The first is by general secondary education (e.g., lyceum) which offer a more theoretical approach to scientifical and technical fields in comparison to full vocational secondary education programmes, which are more focused on practical aspects. Students need to make their choice at age 15. Students of both pathways have different background knowledge and skills entering HE and remedial courses are often offered as a part of bachelor programmes.

According to current statistics published by the Czech Ministry of Education (MSMT, 2024), the distribution of graduates of secondary education system in Czechia between these pathways has been fairly constant for the last decade as 43% of students graduated in full vocational secondary education programmes and only 25% at general education schools. The rest of secondary education students in Czechia graduated secondary education programmes with vocational education training certificates, with no direct possibility of continuation to tertiary education.

The official statistics pertaining to HEI *engineering* programmes applicants show that 57% come from full vocational secondary education programmes and 41% come from general secondary education (MSMT, 2024). These statistics are different in the Prague’s metropolitan area where 60% of applicants come from general secondary education and only 40% come from full vocational secondary education.

This trend may result from 1.) differences in programme portfolio at technical universities that are more academically oriented and/or 2.) composition of secondary education in this region in favour of general secondary schools. The percentage of students admitted to, and graduating from, HE engineering programmes are similar for each pathway and there is not considered to be a significant difference in terms of graduate success rate from different secondary education paths.

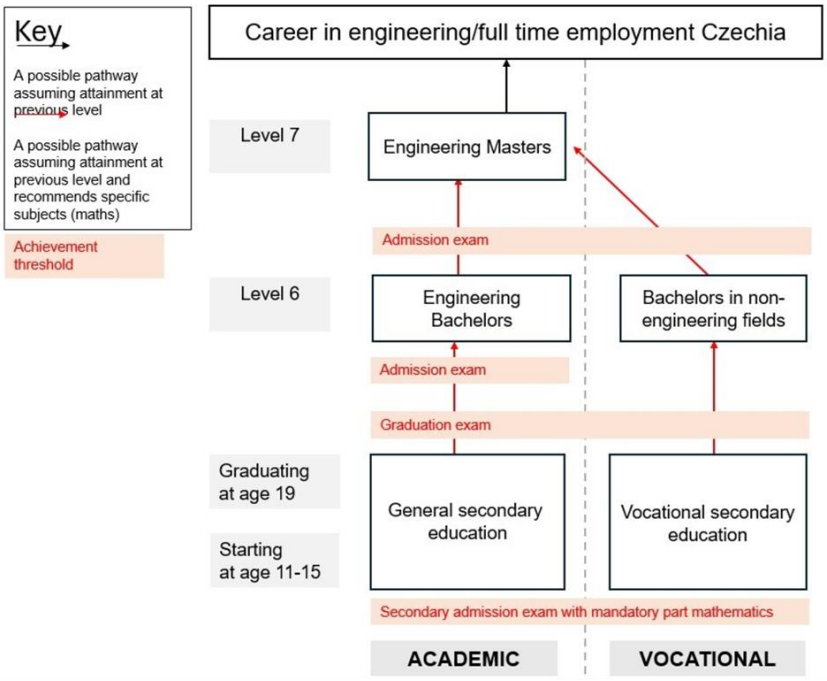

Figure 2: Schematic showing pathways to engineering in Czechia

United Kingdom (UK)

The UK is a Type 4 system, in which at least one stream of qualifications do not allow access to HE and in which HEIs typically select with additional criteria.

Professional titles of Engineering Technician (EngTech), Incorporated Engineer (IEng), and Chartered Engineer (CEng) can only be used by those to whom they are granted through registration with the Engineering Council. The CEng is open to anyone demonstrating the required competences, the application process being more straightforward for those with academic qualifications to masters level. In 2019, 23.4% of those working in engineering occupations studied engineering degrees with 33.9% having a degree or equivalent as their highest qualification and 39.4% having A-Levels or equivalent (ONS, 2019).

Defining the parameters of what constitutes an ‘engineering-facilitating educational pathway’ is difficult as shown in Figure 3. The options chosen at each point have long-term implications and potential to restrict future opportunities. This is considered particularly detrimental to engineering which does not feature in the national curriculum. Young people not aware of engineering are less likely to consider it as a career or understand the educational pathways required to pursue it (Engineering UK, 2020). Access to engineering is therefore seen as correlated with access to high-quality careers advice and guidance (teachers and peers). It is unusual for STEM teachers to have experience or expertise in engineering, and it is likely only to be mentioned by teachers with a specific personal interest.

Subjects and qualifications required to study engineering vary between HEI, with some (often those of lower status/ranking) accepting vocational qualifications. Non continuation data published by HESA (2022) shows the percentage of entrants to

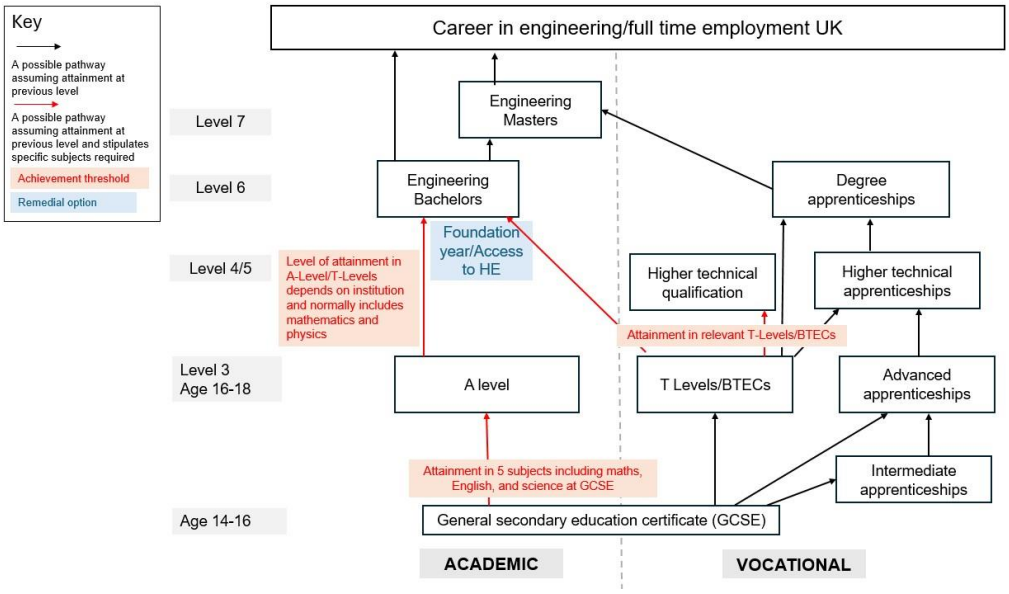

Figure 3: Schematic showing pathways to engineering in UK

engineering degree courses who are no longer in HE is relatively high for those entering with vocational BTECs, compared to A-Levels as well as compared to those with BTECs entering other degree disciplines. Despite the variety of qualifications held by the engineering workforce, there is some consensus on the most relevant subjects recommended to keep options open. It is widely accepted that mathematics and physics are important at secondary level and are often prerequisite at A level to study engineering and technology degrees.

4 SUMMARY

The findings demonstrate that despite differences, all three education systems feature important crossroads in the trajectory into engineering at ages 14-16 and 18. These are important moments to raise awareness of the consequence of choices. Remedial routes are considered important (e.g., in Belgium, the route recently became more difficult), but are difficult to maintain in light of increasing student numbers and pressure for quality education, particularly in open admission systems. Exploration of pathways via apprenticeship, like in the UK, may be beneficial.

This paper presents findings from an initial pilot phase of an exploratory study focused on understanding national education systems and admissions practices in the three European countries in which the authors reside, namely Belgium (Flanders), Czechia, and the UK. In future it would be beneficial to extend analysis to include more countries. It would also be of interest to explore any relationships between education and admissions systems, and factors such as cohort diversity, retention, attainment, and employment opportunities, particularly pertaining to reasons different groups are lost at various crossroads. It is also of interest to further understand pathways to becoming a chartered engineer and levels of retention within the workplace having completed an engineering degree. Obtaining an understanding pertaining to countries within Europe would allow for identification of patterns which may be used to inform future practice in engineering attractiveness.

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