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Enhanc(e)ing engineering education in Europe – cross-national perspectives on challenges and opportunities for university teaching practices

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ABSTRACT

This study investigates the dynamics influencing engineering education within Europe. Its aim is to understand how educators perceive the influence of structural conditions on their educational practices across different national and institutional contexts. Using the ENHANCE Alliance as a case study, survey data were collected of engineering educators from five technical universities across four countries. Quantitative and qualitative analyses reveal significant disparities in teaching practices, available resources, and institutional support. Findings highlight challenges such as the undervaluation of teaching compared to research, insufficient funding, and limited pedagogical training among educators. Furthermore, educators called for stronger links between education and industry, interdisciplinary collaboration, and targeted professional development. These results underscore the importance of context-specific approaches to improving engineering education, including institutional support structures, policy alignment and European-level coordination, resource allocation, and hybrid roles that integrate industry expertise into academia.

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European University Initiative; institutional change; faculty attitudes; educational development; instructional methods

1. Introduction

'Today, our society needs more than ever the contribution of its universities' (European Commission 2022, 1) to face global challenges and to 'drive the transformation towards a more sustainable, resilient and inclusive Europe, to cooperate and co-create knowledge within different European and global cultures, in different languages, across borders, sectors and academic disciplines' (Council of the European Union 2021a, 11). Engineering, in particular, is central to addressing these challenges, as it provides the tools and knowledge to develop innovative and sustainable solutions and thus, contributes significantly to the achievement of the Sustainable Development Goals (Martin et al. 2022; SEFI 2025; UNESCO 2021). This growing societal demand for transformation is also reshaping expectations toward engineering education, placing emphasis on cross-border

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collaboration, shared responsibility, and broader educational missions beyond technical expertise (Cech 2014; Gardelle, 2025; Habbal et al. 2024; Hadgraft and Kolmos 2020).

In parallel, policy efforts such as the European Higher Education Area (EHEA) aim to create a more coherent and aligned educational landscape. It is part of the Bologna Process, which was launched over 25 years ago to promote comparability, mobility and mutual recognition across European higher education systems (Bologna Working Group on Qualifications Frameworks 2005). The Bologna Process has led to important structural reforms, such as the reduction of mobility barriers, greater harmonisation regarding terminology, and the understanding of qualification objectives and quality assurance. At the same time, it has highlighted key tensions, including the push for standardisation the adaptation of shared values, and the challenge of preserving cultural and national diversity in a competitive academic environment (Gardelle et al. 2016; Gunn 2020; Jungblut, Maassen, and Elken 2020).

Building on these foundations, the European Commission (EC) launched the European Universities Initiative (EUI) as part of the European Strategy for Universities to deepen transnational cooperation (European Commission 2022; 2024). The EUI has been recognised as an important driver that operationalises key ambitions of the Bologna Process, especially by supporting the recognition of qualifications, mobility and the development of joint educational programs (European Commission 2025). The EUI aims to foster a 'genuinely European dimension in the higher education sector, built on shared values' (European Commission 2022, 3) and to promote 'a true European identity' while enhancing quality and competitiveness (5f.). Since 2018, higher education institutions (HEIs) have been invited to form European Universities Alliances (EUAs), designed to remove barriers to collaboration and enable the sharing of best practices in education and research (Craciun et al. 2023, 10; Fuchs et al. 2022). These alliances form a 'network of networks', emerging from bottom-up initiatives yet connected through a top-down strategic framework sharing common goals and values (Gunn 2020, 18). As of 2024, the EUI encompasses 65 EUAs with more than 560 HEIs of different types across Europe (European Commission 2024).

However, it is known that differences in national regulations and institutional autonomy create complex challenges for the EUI, particularly concerning governance, long-term funding, degree recognition, lack of resources, and legal and administrative barriers (Craciun et al. 2023; European Commission 2025). There are also still major differences in the academic systems of European countries (Cavalli and Moscati 2010). In a comparative cross-country study, Cavalli and Moscati (2010) showed how varying academic systems in five European countries (Finland, Germany, Italy, Norway, and the UK) affect academic staff working conditions. Key issues include the shift towards more fixed-term contracts, increased hiring from external fields, and differences in how teaching and research roles are balanced. Additionally, the study highlights variations in career progression, mobility opportunities, and job satisfaction across these countries.

These structural differences are also relevant in engineering education, a field that reflects broader academic trends while grappling with its own distinctive challenges. As Lucena et al. (2008, 442) note:

> Europe provides a case in which the challenge is to supplement country-based identities with an emergent regional identity, creating a circumstance in which European engineering educators maintain a delicate balance between, on the one hand, national and institutional autonomy over competencies and accreditation, and, on the other, a commitment to European mobility.

By 2005, the *European Society for Engineering Education* (SEFI) had established itself as a key platform for advancing the Bologna Declaration in the field of engineering education in Europe. Through initiatives, networks and quality assurance measures, such as EUR-ACE, SEFI and other stakeholders have sought to promote comparability and transnational recognition while respecting the historical and cultural diversity of national systems (Augusti 2007; Lucena et al. 2008). Despite these efforts, research indicates persistent disparities among European HEIs that continue to pose challenges to delivering effective and purposeful engineering education, emphasising aspects such as curriculum

design, integration of research activities and support for international exchanges. These differences are rooted in historically diverse engineering education systems (Gardelle et al. 2016; Lemaître 2016). Differences in the operationalisation of curricula and in the implementation of the European Qualification Framework across national systems as well as inconsistencies in qualification objectives lead to challenges for comparability (Pappa, Prummer, and Pittich 2021; Segalàs et al. 2009; Winkens and Leicht-Scholten 2023). Further, there are differences in national accreditation systems (Gardelle et al. 2016), and teaching methods (Corlu et al. 2018), and more broadly in the academic systems and national policy frameworks (Cavalli and Moscati 2010; Ilieva et al. 2019). However, while quality assurance mechanisms such as accreditation standards like EUR-ACE provide formal procedures and objectives, they may overlook broader pedagogical and societal purposes of engineering education. Our study, therefore, does not assume that harmonisation automatically leads to better educational quality, and we acknowledge that what constitutes 'quality' education depends on individual judgement 'about what is educationally desirable' (Biesta 2007, 5). Nonetheless, as our research is grounded in a European context shaped by shared values such as inclusion, sustainability and cross-border cooperation, we frame our research within these broader educational purposes.

To better understand these dynamics, this study focuses on the specific disciplinary context of engineering education by investigating how educators experience the influence of structural conditions on their teaching practices. By 'structural conditions', we refer to the contexts in which HEIs operate – specifically at the institutional (i.e. university), national (i.e. country-level policies) and European policy levels – that shape, though do not determine, educators' teaching practices (see also Archer 2005; Leibowitz et al. 2015).

Based on this, we propose the following research questions:

RQ1: How do educators perceive the impact of national political conditions on engineering education practice?

RQ2: What structural conditions do educators perceive as influencing engineering education practice?

RQ3: To what extent do differences in those conditions lead to different teaching practices in engineering education?

Addressing these questions requires a comparative analysis of institutions across European countries. To date, and to the best of our knowledge, no comprehensive cross-national comparison of higher engineering education systems in Europe exists, making such an analysis essential for elevating educational development within this domain.

Specifically, this study focuses on the ENHANCE Alliance as part of the EUI. It comprises ten large, leading European technical universities, including members from Poland, Sweden, Norway, Germany, Switzerland, Spain, the Netherlands and Italy (ENHANCE, n.d.). The alliance aims to build a shared model of higher education that promotes inclusivity, sustainability, and societal impact through mobility, digitalisation, and interdisciplinary collaboration (ENHANCE, n.d.). By combining its collective expertise, the alliance seeks to address global challenges in line with the SDGs and strengthen student-centred, future-oriented engineering education across Europe. Thus, ENHANCE provides a highly relevant context to explore how shared European values and sustainability imperatives shape engineering education practice at the intersection of institutional practice, structural differences, and transnational cooperation. Since all members of ENHANCE are (technical) universities, we will be using this term henceforth instead of referring to HEIs.

To explore the research questions, we designed and evaluated a survey using both qualitative and quantitative approaches. The findings provide not only insights into perceived challenges and opportunities for enhancing engineering education, but also into overcoming the challenges identified. This includes addressing the misalignment of teaching and research, closer engagement with practice, and systematically developing (missing) teaching skills. In addition to offering specific recommendations for engineering education, this work discusses implications for engineering education research, policymakers, and practitioners aiming to strengthen higher education frameworks in Europe. By addressing the structural and policy-level discrepancies outlined above, the study

contributes to the development of actionable strategies to support the future of engineering education in Europe.

2. Related research

In this section, we provide a brief overview of the literature on the role of educators and the challenges they face in enhancing educational practice in engineering education. This literature also underpins the survey instrument that was developed for this study.

Education plays a critical role in supporting students' competency development, i.e. their qualification, and shaping their ability to engage with complex real-world challenges. It is widely accepted that active learning strategies aligning a student-centred view, such as collaborative learning, problem- and project-based learning, and design-based learning, positively influence students' learning (e.g. Felder, Brent, and Prince 2011; Prince 2004; Prince and Felder 2006). Engineering educators, in their roles as teachers and mentors, but also as leaders, shape not only how students approach learning and contribute to their development as responsible engineering professionals but also have an important role in educational change and curriculum development (Cutler and Coso Strong 2023; Finelli, Daly, and Richardson 2014; Kolmos, Hadgraft, and Holgaard 2016). However, in engineering and STEM education in general, traditional teaching methods continue to dominate, whereas the use of effective and innovative teaching pedagogies is limited (e.g. Borrego and Henderson 2014; Felder, Brent, and Prince 2011; Graham 2018; Hadgraft and Kolmos 2020; Trevelyan 2019). A trend towards more student-centred learning, contextual and practice-based learning, digital learning and a focus on professional competency development is evident, but these approaches are often siloed in single courses (Hadgraft and Kolmos 2020). For decades, there has been a persistent call to improve teaching practice and to transform institutional cultures (e.g. Borrego and Henderson 2014; Cutler and Coso Strong 2023; Graham 2012, 2018; Habbal et al. 2024). Yet, research does not necessarily change educational practice (Cutler and Coso Strong 2023; Kolmos 2015). Moreover, educators in engineering disciplines are often not aware of the growing and relevant body of research in this field (Dart et al. 2024), i.e. it 'is not necessarily accessible to those who need to apply it' (Borrego and Henderson 2014, 221). In this context, the emphasis on identifying 'what works' remains important, especially in a profession that operates on the principle of applying knowledge to improve systems and solve problems, such as engineering (Biesta 2007). At the same time, as Biesta (2007; 2009) reminds us, effectiveness alone is not enough – we must also ask what engineering education is *for* and what kind of outcomes we seek to achieve. Thus, meaningful improvement in engineering education must combine evidence-informed practices with a clear sense of educational purpose.

Beyond frameworks for change and despite several proposed inquiries for improving engineering education, such as programs for faculty members' professional development in teaching, research has shown that engineering educators face several challenges and barriers regarding educational enhancement.

First, teaching is undervalued compared to research (Borrego and Streveler 2015; Dart, Trad, and Blackmore 2021; Graham 2018, 2019; Lattuca, Bergom, and Knight 2014; Pitt and Mewburn 2016). Findings from the last two iterations of the comprehensive and collaborative *Teaching Cultures Survey* (Graham 2020, 2022) indicate that a majority of respondents viewed university teaching as undervalued and even detrimental to career progression; only one in four participants believed that time dedicated to teaching positively impacts career advancement. Additionally, university teaching was not generally seen as a priority within institutions, confidence in appraisal systems was low, and support for change was high. Moreover, the survey reveals differences in perceptions by seniority, where especially mid-career academics (e.g. research fellows, lecturers, assistant and associate professors) are most likely to indicate that their institution placed low value and importance on university teaching.

Second, specifically in engineering, most people engaged in teaching are trained in an engineering discipline and are not trained to do teaching (Borrego 2007; Borrego and Streveler 2015; Dart,

Trad, and Blackmore 2021; Felder, Brent, and Prince 2011). The often-reported absence of practical experience in engineering curricula and the lack of industry-experience leads to students becoming faculty members who tend to apply teaching approaches they learned in their education (Felder, Brent, and Prince 2011; Trevelyan 2019). At the same time, research has shown that activities for professional development for teaching, i.e. taking a workshop or experience in industry, may positively influence the use of active learning pedagogy (Lattuca, Bergom, and Knight 2014; Nørgaard et al. 2023). A supportive institutional environment can also foster innovation in education, especially in terms of collaborations with people from other disciplines (Borrego and Newswander 2008; Cutler and Coso Strong 2023; Lattuca, Bergom, and Knight 2014; Nørgaard et al. 2023). However, there is often a lack of institutional structures that promote collaborations and pedagogical training (Dart, Trad, and Blackmore 2021; Kövesi et al. 2022; Nørgaard et al. 2023). Kövesi et al. (2022) found that continuous pedagogical development may not be sufficiently valued or prioritised at some institutions. While training is often emphasised for junior academics, it appears to be considered less necessary for senior staff members that often prefer collegial exchange over formal training (Kjellberg et al. 2023; Kövesi et al. 2022). Furthermore, if pedagogical training is not consistently valued across the organisation or throughout an academic career, informal incentives to pursue such development are likely to weaken. This may be associated with the problem that professional development offers in engineering are often provided by social scientists in centralised teaching centres to university-wide faculty where discipline-specific examples are absent (Felder, Brent, and Prince 2011). Correspondingly, meaningful incentives for engineering staff to participate in educational development are lacking.

Third, time constraints hinder educators in designing and delivering purposeful and effective teaching (e.g. Dart et al. 2024; Finelli, Daly, and Richardson 2014; Henderson, Beach, and Finkelstein 2011; Shadle, Marker, and Earl 2017; Siddiqui et al. 2016). This goes together with other structural obstacles, such as the alignment of government and higher education goals, challenges in reconciling the need for student-centred teaching with large student cohorts, a strong disciplinary focus in engineering departments, a general resistance to change, low recognition from colleagues and lack of funding (e.g. Graham 2018, 2019; Henderson, Beach, and Finkelstein 2011; Shadle, Marker, and Earl 2017; Siddiqui et al. 2016).

In a recent study, Dart et al. (2024) examine key factors that impact engineering educators' teaching practices within Australian universities. Utilising Bourdieu's Theory of Practice, they highlight the influence of both 'capital' (values within the academic field) and 'habitus' (educators' personal and professional dispositions). Five capital factors emerged: engineering subject knowledge, knowledge of educational practices, recognition of teaching quality, resource allocation, and collegial networks. These factors underscore the importance of expertise and peer support, as well as structural barriers such as under-recognition of teaching, and insufficient time and funding. Additionally, four habitus-related factors were found: role context, personal motivation, subject and student characteristics, and institutional context. For instance, educators in permanent roles or with strong teaching motivation were often more engaged with teaching practices, even when resources were scarce. Institutional context, particularly in the form of organisational support and alignment between teaching and research incentives, was critical for fostering an environment conducive to teaching innovation. These findings illustrate the relevance of the complex reciprocity between the individual level of educators and the institutional level of the higher education institution (, Cutler and Coso Strong 2023; Kolmos, Hadgraft, and Holgaard 2016). Institutional structures can be described as 'a nesting doll of contexts and influences that impact both students and faculty' (Cutler and Coso Strong 2023, 291) and educators are embedded in a broader academic system shaped by diverse political and cultural conditions (Leibowitz et al. 2015; Wolff, Hattingh, and Smith 2025).

In summary, educators' efforts to improve teaching and learning in engineering education face persistent challenges at multiple levels, including institutional barriers within universities and departments, national policy constraints, and cultural attitudes toward teaching and research.

3. Methodology

To answer the research questions, we use a comparative method design that uses quantitative and qualitative data gathered through a survey conducted among engineering educators at European technical universities. The quantitative approach was chosen to identify trends and patterns in teaching practices, as well as to examine correlations between teacher's attitudes, structural conditions and teaching practices. The qualitative part complements this by providing deeper insights into the nuanced perceptions and experiences of engineering educators from different European countries. By combining a quantitative survey design with qualitative analyses, the study seeks to capture the complexity of teaching practices in engineering education across diverse European contexts.

3.1. Survey design and data collection

The questionnaire was developed and reviewed collaboratively by researchers from Chalmers University of Technology (Chalmers), the Norwegian University of Science and Technology (NTNU) and RWTH Aachen University (RWTH), ensuring both academic rigour and relevance. The development of the survey items was guided by prior research, including the *Teaching Cultures Survey* (TCS, Graham 2020, 2022). Building on the results from the TCS, we included specific demographic questions in our survey, such as employment status (e.g. full/associate/assistant professor, lecturer, PhD, etc.), employment duration, type of position (permanent or temporary), and teaching obligations. These variables were selected based on TCS findings, which highlighted their importance in understanding differences across groups, and we assumed similar variations in our context. Additionally, several questions on teaching attitudes – such as commitment, the impact of teaching on career progression, and the relevance of pedagogical training – were informed by the TCS. Questions regarding motivational and hindering factors were derived from the existing literature presented earlier in this study. The results in terms of these factors were previously published in Winkens et al. (2024) and are thus not part of this study.

To ensure the quality of the questionnaire, a pre-test was conducted with selected participants. Based on their feedback, no major changes were required; however, some items were revised for clearer wording and additional items were included to enhance comprehensiveness.

The final questionnaire consisted of 21 questions on teaching experiences, the use of teaching and learning methods/approaches, attitudes towards teaching, motivational and hindering factors in teaching, as well as on political framework conditions. Demographic variables were included to analyse group-specific differences. If not specified otherwise, all answers were given on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). For an overview of all items and their encoding, we refer to the Appendix.

The data was collected from engineering educators at the ten technical member universities of the ENHANCE Alliance. The survey was distributed via email to university representatives, who were asked to share it with relevant faculty engaged in engineering education. The response rate could not be determined, as the total number of faculty who are engaged in engineering education and received the invitation remains unknown. Data was collected anonymously using the SoSci Survey platform from July to November 2023.

Five of the ten ENHANCE universities participated in the study. Table 1 summarises the key figures for each university.

3.2. Data set

Overall, 489 participants completed the survey. We excluded the data corresponding to all participants who either indicated that they are not engaged in engineering education or who did not give information on their type of position. This resulted in a final data set of 453 entries divided

Table 1. Key figures of participating ENHANCE universities (rounded figures, taken from the respective university websites or if not available based on internal non-public documents*).

University	Abbreviation	Country	Students (incl. PhD)	Academic Staff
Chalmers University of Technology	Chalmers	Sweden	12,000	1000
Gdańsk University of Technology	Gdańsk Tech	Poland	14,000*	1,200*
RWTH Aachen University	RWTH	Germany	45,000	7,000
Warsaw University of Technology	WUT	Poland	21,000*	2,500*
Polytechnic University of Milan	Polimi	Italy	48,000	2,000

between the five universities Chalmers (16), Gdańsk Tech (164), Polimi (113), RWTH (77) and WUT (83). Table 2 shows the distribution of participants both overall and with regard to the individual universities.

The participants of the survey teach in various engineering disciplines, most of them in computer (91), civil (89) and/or mechanical engineering (86). Other frequently represented disciplines are electrical, chemical, industrial and environmental engineering. A few participants teach in the disciplines of biomedical, materials, business or transport engineering.

3.3. Data analysis

As seen in Graham (2020; 2022), different staff positions often have differing perspectives, which may be linked to variations in perceived motivations and barriers, highlighting the importance of considering diverse academic roles in engineering education research. In this study, we did not adopt Graham's distinction for the staff position. Instead, we categorised participants into two groups: the professors, which includes full, associate and assistant professors, and the non-professors, which includes (senior) lectures, research associates, Post-Doctoral and PhD students. As such, we differentiate between the two in our analysis. All quantitative data was evaluated using R and Python (scipy, pandas, sklearn).

3.3.1. Quantitative data

We used descriptive and inferential statistical techniques to explore patterns and relationships within the data. First, descriptive statistics are provided for all items, treating Likert scales as metric data. Note that Likert scales are ordinal by nature, and that the extent to which they can be treated as metric is subject to debate, see Kusmaryono, Wijayanti, and Risqi (2022). For all items we provide mean values (MV) and standard deviations (SD), grouped together by categories. Second, we evaluate linear correlations, for which we always use Pearson's correlation coefficient (r). For the quantitative analysis of potential differences between universities, the non-parametric Kruskal–Wallis test was applied, as preliminary tests indicated that no normal distribution of the data could be assumed. For significant Kruskal–Wallis results, we performed a post-hoc Dunn's test. A significance level of $p < .01$ was used for all tests.

Due to the small sample size for Chalmers (16), results specifically relating to this university should be interpreted with caution and are not to be considered representative for engineering education at Chalmers.

Table 2. Survey participants by university, gender and employment status.

Item		All	Chalmers	RWTH	Gdańsk Tech	Polimi	WUT
University		453	16	77	164	113	83
Gender	Male	297	11	53	107	84	42
	Female	134	3	18	50	26	37
	Non-binary	1	0	0	1	0	0
	No answer	21	2	6	6	3	4
Employment Status	Professor	379	11	50	143	110	65
	Non-Professor	74	5	27	21	3	18

Finally, we performed a linear regression with teaching methods as a dependent variable (observable outcome), and all other items as independent variables to measure the extent to which the responses to the survey can explain the choice of teaching methods. Fit is evaluated based on ordinary least squares, using the adjusted coefficient of determination ($\underline{R}^2$) as a measure of fit.

3.3.2. Qualitative data

For the analysis of the qualitative survey data, we applied reflexive Thematic Analysis (TA) as outlined by Braun and Clarke (Braun and Clarke 2006, 2019). We chose TA to more thoroughly understand the *reasons* for possible differences between participants' universities through incorporating different perspectives. This method allows for a nuanced and flexible engagement with our qualitative data, which consists of free-text responses from two specific items: the question related to 'Political Framework Conditions' and the survey's concluding 'Further Comments' section. Our approach was structured but reflexive, considering the complex interplay between the data, the researchers' positionality, and the broader research context (Braun and Clarke 2019).

To be comprehensive, three researchers from different academic backgrounds and epistemological perspectives (engineering, political science and mathematics) approached the data, as we assumed that an interdisciplinary composition may add richness and flexibility to the analysis. The first three authors approached the free-text responses to gain understanding of the content and context of the participants' comments. For the coding approach, we first generated initial codes independently and inductively to preserve the diversity of interpretations. Our intention was to allow themes to develop from the participants' language and framing rather than imposing pre-existing concepts. The coded data were reviewed collaboratively to identify patterns of shared meaning, particularly regarding the political framework conditions. We focused on how participants framed their understanding and experiences of political influences, iteratively refining these themes. For the 'Further Comments' section, we explored patterns that aligned with the political themes while remaining open to new insights. We then used an inductive approach to ensure additional topics were adequately represented, allowing themes to evolve in response to the data. Our analysis was aimed at constructing a cohesive narrative that synthesised the identified themes. We sought to tell a *story* of the data (Braun and Clarke 2019), highlighting contextual nuances and the multifaceted meanings *participants* attributed to the political framework conditions in their respective countries as well as their perspectives on quality in engineering education. This narrative underlines the importance of researcher subjectivity as a resource rather than a limitation, aligning with the emphasis of Braun and Clarke (2019, 2020) on active meaning-based qualitative research.

4. Results

This section presents the findings of the study, structured to address the three research questions. Section 4.1 focuses on the quantitative results, beginning with an analysis of RQ1 concerning the perceived impact of national political conditions on educational practice in engineering education. This is followed by an exploration of teaching attitudes and teaching methods to provide an overview of structural and personal factors impacting teaching practices (RQ2 and RQ3).

In Section 4.2, the qualitative results of the thematic analysis are presented. These findings complement and expand upon the quantitative results for the three research questions by offering deeper insights into educators' perceptions. Additionally, this section highlights educators' suggestions for change, outlining practical implications for improving educational practice and cohesion in engineering education.

4.1. Quantitative results

4.1.1. Political framework conditions

The quantitative data on political framework conditions refer to the availability of funding opportunities at national, university and faculty level, and whether the national policy framework enables or prevents educators in improving their teaching. The means, standard deviations and the *p*-value of the Kruskal–Wallis test for the political framework conditions are shown in Table 3.

In the provided data, there is a noticeable contrast in how participants perceive the national political framework's role in supporting improvements in educational practice. The item 'The national political framework in my country enables me to improve my teaching' (Enabling Policies) shows significant differences between universities ($p = 0.007$). The post-hoc test indicates that participants from RWTH display significantly higher agreement than those from Polimi.

4.1.2. Teaching load and attitudes

Overall, 418 participants reported on their teaching load. Participants spend on average 60% of their work time on teaching, with a third of participants spending over half of their time on teaching. This number is higher than average in Gdańsk Tech (76 out of 164) and WUT (31 out of 83). There is a strong correlation (r = .88) between teaching load and obligation to teach, with 24 participants reporting that they teach less than required, and 90 participants reporting that they teach more.

The analysis of teaching attitudes across universities reveals several key differences and similarities in how educators perceive their role and responsibilities. Table 4 provides an overview thereof.

First, there are significant differences in satisfaction with engineering education at participants' own universities (EE Satisfaction). The post-hoc test shows that Polimi participants are significantly more satisfied than participants from RWTH, Gdańsk Tech and WUT. Moreover, engineering

Table 3. Means and standard deviations for teaching-related policy and funding conditions. *p*-values for differences between universities (Kruskal-Wallis), bold: significant at $p < 0.01$.

	All		Chalmers		RWTH		Gdańsk Tech		Polimi		WUT		*p*-value
	MV	SD	MV	SD	MV	SD	MV	SD	MV	SD	MV	SD	group difference
National Funding	2.9	1.1	2.6	1.1	3.3	0.9	2.9	1.1	2.3	1.0	3.0	1.0	**< 0.001**
Uni Funding	3.3	1.0	3.3	1.1	3.5	0.8	3.3	1.0	3.2	1.1	3.1	1.0	0.068
Faculty Funding	3.1	1.1	2.9	1.2	3.2	1.0	3.0	1.1	3.1	1.1	3.0	1.1	0.345
Enabling Policies	2.4	1.0	2.7	1.0	2.8	1.1	2.4	1.1	2.1	0.9	2.3	0.9	**0.007**
Preventing Policies	2.9	1.1	2.9	0.7	2.7	1.0	2.9	1.1	2.8	1.1	2.8	1.1	0.083

Table 4. Means and standard deviations for teaching attitudes by university.

	All		Chalmers		RWTH		Gdańsk Tech		Polimi		WUT		*p*-value
	MV	SD	MV	SD	MV	SD	MV	SD	MV	SD	MV	SD	group difference
EE Satisfaction	3.6	0.9	3.5	1.1	3.3	0.9	3.4	1.0	4.1	0.6	3.6	0.9	**< 0.001**
EE Training	3.7	0.8	4.0	0.6	3.5	1.0	3.7	0.8	4.0	0.7	3.7	0.8	**0.002**
No Pedagogic	2.3	1.0	1.8	0.8	2.2	0.9	2.4	1.0	2.1	0.7	2.4	1.1	0.023
EE Commitment	4.3	0.7	4.5	0.5	4.3	0.8	4.2	0.7	4.4	0.7	4.4	0.7	0.097
EE Peer Commitment	3.8	0.8	3.9	0.8	3.9	0.7	3.6	0.8	3.9	0.8	3.9	0.7	0.013
EE Uni Commitment	3.9	0.8	3.9	1.0	4.0	0.8	3.7	0.9	4.3	0.7	4.0	0.7	**< 0.001**
EE Focus Wish	3.7	0.9	4.1	1.0	3.6	0.9	4.0	0.8	3.4	0.9	3.8	0.8	**< 0.001**
Bottom-Up	3.5	0.9	3.3	0.7	3.4	0.9	3.7	0.8	3.4	0.9	3.7	1.0	**0.001**
Top-Down	3.7	0.8	3.4	0.8	3.7	0.9	3.8	0.8	3.6	0.8	3.7	0.8	0.029
Positive Career Impact	2.8	1.2	2.7	1.2	2.7	1.1	2.9	1.2	2.4	1.1	3.3	1.2	**< 0.001**
Negative Career Impact	3.0	1.2	3.3	1.2	2.8	1.0	3.1	1.2	3.2	1.1	2.7	1.3	0.011
Obligatory Teaching	2.1	1.2	1.7	0.8	1.8	1.0	2.6	1.2	1.7	0.9	2.1	1.3	**< 0.001**

Note: *p*-values for differences between universities (Kruskal-Wallis), bold: significant at $p < 0.01$.

educators in this survey generally report low agreement with the statement that they teach primarily because it is a compulsory task (Obligatory Teaching). However, significant differences exist between universities ($p < 0.001$), with significantly higher agreement at Gdańsk Tech. It was also found that professors (MV = 3.8, SD = 0.8) feel significantly ($p < 0.001$) more sufficiently trained to educate engineers well than non-professors (MV = 3.2, SD = 1.0).

Participants largely agree that their universities are committed to educating engineers well (EE Uni Commitment). However, significant differences arise regarding institutional commitment ($p < 0.001$). According to the post-hoc test, Polimi participants agree with this statement more often than participants from Gdańsk Tech and WUT. Significant differences also exist in terms of the desire to have a stronger focus on improving engineering education (EE Focus Wish, $p < 0.001$), insofar as participants from Polimi agree with this statement less often than participants from Chalmers, WUT and Gdańsk Tech.

4.1.3. Teaching methods and constructive alignment

Considering the use of teaching methods, Table 5 summarises the data on these and constructive alignment (CA) across the universities. The Kruskal–Wallis test shows significant differences in the use of teaching methods and attitudes towards constructive alignment between the universities, except for flipped classroom (Flipp. C).

All institutions show similar reliance on lectures as a teaching method, though the post-hoc Dunn's test indicates that lectures are used significantly more often at Polimi compared to RWTH, WUT and Gdańsk Tech. Problem- and project-based learning (PjBL) is another favoured method, which, according to the post-hoc test, is used significantly less often at RWTH and Polimi than at the other universities. The same pattern of use also applies to collaborative learning (Coll. L.).

When comparing the teaching methods used by professors and non-professors, significant differences were only found for lectures. Professors lecture significantly more often than non-professors, with a mean of 4.3 compared to 3.5. Despite this, both groups favour lectures as their primary method of instruction. We also tested for a correlation between the applied teaching methods and the duration of teaching experience, but there is none, indicating that teaching duration does not influence the adoption of these methods.

We also asked the participants to what extent they are familiar with (CA Fam.) and applying the concept of constructive alignment (CA Appl.) (Biggs & Tang, 2011) and to what extent they would like to learn more about teaching and learning methods. Participants who know constructive alignment also apply it in their teaching (r = .81). Participants from Chalmers by far report the highest levels of both familiarity and application. Polimi participants, on the other hand, show significantly lower values, indicating no systematic integration of CA in teaching practices. Despite

Table 5. Means and standard deviations for teaching methods and constructive alignment by university. *p*-values for differences between universities (Kruskal-Wallis), bold: significant at $p < 0.01$.

	All		Chalmers		RWTH		Gdańsk Tech		Polimi		WUT		*p*-value group difference
	MV	SD	MV	SD	MV	SD	MV	SD	MV	SD	MV	SD	
P(j)BL	3.5	1.0	4.1	0.7	3.2	1.2	3.7	0.9	3.1	1.3	3.6	1.1	**<0.001**
CBL	2.7	1.2	2.7	1.5	2.3	1.2	3.1	1.0	1.8	1.0	3.1	1.3	**<0.001**
Lecture	4.1	1.0	4.1	1.3	4.1	1.1	4.0	1.0	4.6	0.6	4.0	0.9	**<0.001**
Case L.	3.1	1.3	2.9	0.7	2.9	1.2	3.4	1.0	2.5	1.1	3.6	1.1	**<0.001**
Coll. L.	2.9	1.2	3.6	1.2	2.5	1.1	3.3	1.1	2.2	1.2	3.5	1.1	**<0.001**
Flipp. C.	2.1	1.1	2.3	1.1	2.3	1.4	2.1	1.0	1.8	1.0	1.9	1.0	0.062
Expl. L.	2.6	1.2	2.5	1.4	2.3	1.1	2.1	1.1	1.9	1.1	2.7	1.1	**<0.001**
Peer L.	2.0	1.0	2.4	1.4	2.0	1.2	2.2	1.0	1.6	0.9	2.2	1.0	**<0.001**
Expi. L.	2.7	1.3	2.9	1.1	2.1	1.2	3.2	1.1	2.3	1.2	2.9	1.3	**<0.001**
CA Fam.	2.5	1.2	4.4	1.3	2.8	1.2	3.0	1.0	1.9	0.9	3.1	1.0	**<0.001**
CA Appli.	2.5	1.2	4.3	1.3	2.6	1.1	2.9	1.0	1.9	0.9	2.9	1.1	**<0.001**
Interest	3.8	0.9	4.0	0.8	3.7	0.8	3.8	0.9	3.6	0.8	4.2	0.7	**<0.001**

these differences, the majority express a strong interest in learning more about the above teaching methods.

Via linear regression, we evaluated to what extent all items assessed in the survey, i.e. motivation, attitudes and political aspects explain the choice of teaching methods. We found that those have little explanatory power ($\underline{R}^2 = 0.11$). The regression for individual universities resulted in a minor increase of explanatory power for Gdańsk Tech and Polimi. Notably, for RWTH the explanatory power is significantly higher: Lectures, peer learning and experiential learning displayed $\underline{R}^2$ values of 0.28, 0.35 and 0.35, respectively, with an average of 0.14 across all items.

4.2. Qualitative results

4.2.1. Impact of political framework

Supplementing the closed questions presented in 4.1.1, we asked respondents to describe how the political framework in their respective countries supports or inhibits good teaching. Our thematic analysis of these responses revealed seven recurring themes: *(Under-)Funding, Pressure to Produce Graduates, Misalignment between Teaching and Research, Bureaucracy, Workload and Time Constraints, Country Specific Tensions with the Ministry of Education,* and *General Satisfaction* with the state of affairs. These themes often intersect, reflecting shared patterns across different institutions. It is noteworthy that all aspects were addressed by both professors and non-professors.

4.2.1.1. (Under-)Funding. A central issue across all five universities is the perceived lack of funding for teaching and education, which is linked to other barriers such as low salaries, unstable financial planning, and lack of resources. Respondents describe this as a 'chronic disease', with limited or unavailable government funding enforcing reliance on third-party funding to improve teaching. Increased governmental financial support would allow teachers to 'focus on their job'.

Competitive grant schemes are criticised as ineffective due to low success rates and the substantial paperwork required. While participants note that some funding opportunities for teaching improvements exist, they often provide only small, short-term amounts, demanding significant time investment for uncertain returns. Additionally, such grants typically favour projects promising 'a new super, mega fresh, innovative, novel, and digital blabla teaching method', making them particularly challenging for doctoral candidates involved in teaching, who are required to invest significant extra time in drafting proposals. Respondents highlight the lack of long-term funding, such as for administrative support, and view the focus on competitive short-term grants as unsuited for fostering lasting teaching improvements. As one instructor noted: 'good teaching is to a large extent the personal contact to the instructor. Would you get funding for this? Does funding replace the instructor's time?'.

This funding theme is closely tied to the perceived misalignment of teaching and research, with research funding seen as more readily available. Furthermore, university funding models often tie financial support to the number of graduates, impacting both teaching priorities and institutional resources.

4.2.1.2. Pressure to produce graduates. Educators consistently reported a perceived pressure from governments and university administrations to prioritise the quantity of graduates over the quality of education. Frustration was expressed with funding models tied directly to graduation numbers or course pass rates. One participant noted,

> Funds given to universities by government depend on numbers of students but not on the quality of teaching, so […] we just try to keep as many students as we can. It is impossible to teach well when there are too many students, and most of them are not interested in subjects […]

This focus on numerical targets often prioritises retention over educational rigour, which respondents argue dilutes the value of university education.

Respondents highlight an emphasis on 'getting degrees' over genuine learning, especially in engineering and STEM. One educator remarked, 'I can't see any rewards for a *good* education; the main focus seems to be on getting degrees (the sheet of paper)'. Limited staffing and resources exacerbate the issue, with institutions relying on third-party-funded researchers to meet teaching demands. Some respondents argue that this system 'kills' educational quality and call for a shift away from enrolment quotas and graduation rates as metrics, advocating instead for policies that allow universities to focus on smaller class sizes, improved educational practices, and meaningful engagement with students' educational journeys.

Increasing demands for accessibility, such as accommodating neurodivergent students, though well-intentioned, are also criticised. Some respondents expressed concerns that extensive accommodations might compromise academic standards and fairness, questioning 'what industry and society should expect from someone holding a university degree'. Respondents noted that the additional burden of adapting exams and assignments (without additional resources) affects their time and ability to support other students.

4.2.1.3. Misalignment between teaching and research. A recurring theme among respondents is a perceived pervasive and often severe imbalance between the value placed on teaching and research in universities. This disparity affects career progression, funding, and professional priorities, with research widely perceived as the primary driver of academic advancement. According to respondents, teaching not only holds less value than research in their respective countries but, as respondents from Italy emphasised, may even negatively impact academic careers.

Participants report that Italian academic promotion criteria focus almost exclusively on research achievements, offering little to no recognition for teaching efforts. One respondent from Polimi explained, 'Teaching does not improve my CV. Yet, enhancing my CV is the only thing that counts toward winning permanent positions in the university'. This results in a system where teaching is viewed as 'lost time' and 'professors are seen as lazy people', detracting from the research output necessary for advancement. As another participant summarised, 'To become a university professor in Italy, you have to be an excellent researcher, and it does not matter if you are a bad teacher'. Similar sentiments are echoed from participants of the Polish universities, where the focus is on 'mass-producing publications based on a point-awarding system that determines university funding'. Educational quality has a 'marginal impact' on performance evaluations, and spending additional time on teaching can be grounds for negative performance assessments. Another respondent stated, 'the less amount of work I spent on teaching, the better for me'. Additionally, teaching-focused positions are criticised for often having lower salaries and fewer opportunities for promotion than those dedicated to research.

While less pronounced in the comments from participants from the German and Swedish universities, the perceived preference for research still dominates. Financial incentives for new teaching initiatives are seen as minimal compared to research funding, making it challenging for faculty to invest time and resources in enhancing educational practices: 'The matter is simple: I am evaluated for my research, not for my teaching, and if I use time for improving my teaching, I have less time for my research'.

Across all five universities, participants report that this research-driven academic environment often leads to teaching as a secondary priority, reducing students to 'necessary evils' within a publication-focused system. Respondents widely agree that unless teaching is better valued within hiring, promotion, and funding processes, meaningful improvements in instructional practices are unlikely to occur, despite faculty members' intrinsic motivation to support student success.

4.2.1.4. Bureaucracy. Respondents across institutions express strong criticism of bureaucracy, describing it as rigid, inefficient and detrimental to educational quality and educator motivation. Bureaucratic hurdles include structural inflexibility in curricula and operational inefficiencies, with educators facing obstacles even in routine tasks, such as procuring teaching materials or adapting

assessments. As one respondent noted, 'A process that could take one minute easily consumes 2–3 days', highlighting the system's inefficiency.

A major source of frustration is the rigidity of national education laws, described as 'immovable' and preventing universities from adjusting to evolving educational needs. This inflexibility is particularly problematic in engineering, where rapid technology advancements and industry demands necessitate regular curricular updates. One educator noted, 'The education system regulated by the law does not allow for flexible management of the educational processes and programs', hindering both educators and students.

Additionally, respondents observe a growing administrative apparatus within universities, diverting resources from teaching. As one stated, 'Universities have been transformed into corporations', where bureaucratic demands take precedence over teaching priorities. Regular changes in higher education laws add further administrative tasks, limiting educators' time for preparation and growth, with 'stupid changes in the law' preventing improvements and sapping motivation.

4.2.1.5. Workload and time constraints. Lack of time is a recurring theme across participants from all universities, often connected to high workloads in teaching, research duties and underfunding. Educators report that heavy workload and teaching responsibilities combined with administrative and research tasks leave little room for course development or improving teaching practices. As one educator stated, 'there is no time for teaching, it just runs beside all other stuff', highlighting that any attempt to improve would 'just mean more work', discouraging efforts to enhance quality.

An additional concern is the disproportionate workload assigned to teaching versus research-focused positions. This disparity results in fewer resources and less recognition for teaching-focused staff, leading one participant to liken their status to that of 'janitors'. Moreover, high student-to-teacher ratios further exacerbate the strain, with some suggesting that smaller classes and more personnel would be necessary to maintain educational quality.

4.2.1.6. Country specific tensions with the ministry of education. This theme is country-specific and necessary because the criticism raised by participants from the Polish universities about their government was on a distinct level and quality. Respondents pointed to preferential treatment of certain people or departments and a perceived disdain for science and engineering. Ideological leanings of the ruling party were seen to foster administrative difficulties and support selective research fields (e.g. theology) that do not pertain to engineering education.

While some claim good intentions, the government's educational reforms were heavily criticised for fostering a culture focused on frequent publications in government-approved journals ('THE LIST') at the expense of teaching and independent research. A recurring concern was the perceived absence of a 'proper Ministry for Higher Education', described instead as a 'pure political position'. The system's structure is described as one that 'prevents good teaching and research at all levels due to deep political engagement'.

The lack of funding and recognition for engineering education reflects broader concerns among participants over the government's impact on intellectual freedom and academic excellence.

4.2.1.7. General satisfaction. While most respondents express dissatisfaction with the current state of education, some offered contrasting perspectives. Several emphasised that political frameworks do not significantly influence their teaching practice. One respondent noted, 'I do believe political frameworks have nothing to do with my teaching', highlighting a sense of autonomy in their educational practices. Having autonomy from policy was also valued by many respondents, e.g. as enshrined in the German constitution's freedom to teach (see Federal Ministry of Justice n.d.).

Some also acknowledged specific institutional efforts, such as government-initiated quality control measures which they felt improved teaching standards. Others pointed out the relevance of personal attitude and motivation, noting: 'Of course I could do more and better having some founds to make my classes more interesting, but the key is the way how I behave and lead the

learning process'. A minority expressed satisfaction with 'traditional teaching' and saw no need for change. Moreover, scepticism toward modern innovation was raised:

> that initiatives that supposedly 'improve' teaching by the extensive use of digital media, remote learning, and some other 'innovative' teaching strategies have a high risk to negatively impact students' knowledge and can indeed contribute to a decline in the average students' skills along the years.

4.2.2. Further influences

In addition to the themes related to political framework conditions, we identified three additional themes in the free comment section. These provide further insights into the reasons and problems behind the current state of engineering education at the universities included in this study. The themes are *Student Preparedness and Motivation*, *Lack of Infrastructure for Teaching and Learning*, and *Teacher Qualifications and Practical Competency*.

4.2.2.1. Student preparedness and motivation. Respondents criticise student preparedness and motivation for engineering and technical fields. They argue that freshmen often lack foundational knowledge or genuine interest in the discipline. As one respondent noted, 'students don't have the basis to understand mathematics and physics, [and] in the last 20 years, the level of preparation of the student has always decreased', leading to a reliance on supplementary instruction that is seen as an inefficient use of resources, i.e. 'a waste of time and competencies of academic teachers'. Societal and economic pressures may play a role in shaping student motivations. One respondent explained, 'many students enter the engineering education not because they are interested in the subjects or because they want to learn, but because they want to get a final diploma so that they can get a good-paying job'.

The COVID-19 pandemic has further exacerbated issues of motivation and self-directed learning, with interest for, e.g. civil engineering reportedly facing a decline as students gravitate towards 'modern' fields. This shift pressures educators to lower academic standards to accommodate less engaged students, leaving 'the few highly motivated students and teachers unsatisfied'. Additionally, lack of preparedness links closely to the theme *Pressure to Produce Graduates.* Respondents highlight that universities enrol underprepared students while adhering to political guidelines on failure rates, undermining academic rigour. As one educator noted, 'The main problem […] is that in many cases students are not capable of studying and do not have the necessary prerequisites'.

4.2.2.2. Lack of infrastructure for teaching and learning. According to respondents, inadequate infrastructure poses several challenges to educational quality in engineering and technical fields, particularly given the high student numbers. Educators indicated that many lecture halls lack essential technology for modern teaching, such as reliable audio systems or streaming capabilities, and even new spaces often fail to meet these demands. Laboratory resources were also described as insufficient, which reduces opportunities for hands-on learning. As one respondent noted, 'there are very few opportunities for students to be exposed to experimental activities', which are crucial to understand complex concepts.

A lack of digital learning platforms and access to diverse educational resources were also highlighted as problematic areas, with universities struggling to adapt to rapidly advancing technologies. One participant highlighted, 'working methods change rapidly thanks to tools like AI', but effective teaching solutions remain underdeveloped. Furthermore, students frequently encounter a lack of diverse educational materials, with resources often explaining concepts 'the same way', failing to address different learning needs. These challenges are reportedly compounded by a shortage of technical and administrative staff for maintaining or upgrading facilities. Collectively, these infrastructural gaps undermine the implementation of innovative teaching methods and reduce educational effectiveness.

4.2.2.3 Teacher qualifications and practical competency. For respondents, a major issue is the lack of structured support for developing teaching skills after earning a PhD. As one respondent observed, 'academic teachers are left alone, without any methodological support in teaching skills', leaving educators ill-prepared to engage students effectively. Teaching complex applied subjects also requires practical experience that many fresh graduates or purely academic professionals lack. 'It is standard that the people immediately after graduation teach mathematics or physics', one participant noted, 'but if we want to teach students how to design, e.g. a bridge, you need experience'. The cultural divide between academia and industry, along with bureaucratic challenges, further restricts the integration of practical knowledge, as 'There is no support for parallel industrial activity enhancing practical competence of the academics'.

Another reported challenge is the generational and technological gap among academic staff. Older professors, despite their expertise, often struggle to adapt to digital and interactive tools familiar to modern students. As one participant observed, 'we have old professors that teach young people entirely immersed in e-culture and a technologically advanced world'. This generational divide leads to a persistence of traditional teaching methods because 'people who have been working at the university for many years […] change neither the content nor the methods of teaching'. Efforts to innovate are often opposed by colleagues unwilling to invest in pedagogical improvement.

Moreover, many academics perceive their teaching methods as effective, discouraging them from adopting new techniques, which is closely linked to the theme of general satisfaction. As one respondent noted, 'people who sometimes dislike teaching will probably never be motivated to improve their educational skills'. Ultimately, effective teaching in engineering requires more than just expertise in research, as one participant highlighted, 'Not everyone should and can teach. […] There are really good researchers who should not meet students'.

4.2.3. Implications for change

Up to this point, we classified and presented the various themes as reasons for the current state of engineering education from the respondents' point of view. Additionally, based on the qualitative responses, we identified specific implications for change, which participants articulated as concrete proposals for solutions. These suggestions were categorised into four overarching themes: *Aligning Engineering Education with Professional Practice*, *Enhancing Teacher Training*, *Fostering Students' Competency Development*, and *Transforming the Educational System*.

4.2.3.1. Aligning engineering education with professional practice. Participants consistently highlight the need to strengthen links between engineering education and practice to enhance program quality and relevance. A central suggestion was to align teaching with the roles and tasks students will encounter in their careers and to reflect on the identity of engineering: 'Engineering education should teach the fundamental ability or skill to solve relevant, real-world problems with particular emphasis on its human-oriented specificity of usefulness'. As one participant noted, 'The university may educate in the forefront of research in some aspects, but it should also educate within present and future roles of engineering'.

Key areas for improvement noted include integrating social and ethical considerations into curricula, fostering interdisciplinary collaboration across traditionally siloed fields like mechanical and electrical engineering, and promoting adaptability to technical change, given that 'change is nature of engineering [*sic*]'. Participants also stressed the importance of strengthening the societal status of engineers to boost student engagement, noting that current demands may deter some from pursuing the field: 'To increase the engagement in students when studying engineering it would be highly beneficial to improve the status of engineers in our country'.

Moreover, strengthening partnerships with industry was seen as vital, with suggestions such as internships, study visits, and collaborative projects involving industry practitioners. This approach

would bridge the gap between theory and practice, ensuring curricula incorporate real-world problems and labour market demands.

4.2.3.2. Enhancing teacher training. Building on the theme of teacher qualifications and practical competency, participants stressed the need for teacher training programs that not only elevate the quality of instruction but also align educators with the evolving demands of engineering education. Additionally, participants highlighted the importance of both pedagogical skills and practical experience. As one educator noted, 'I would like to learn some new techniques of teaching. In fact, I have been never taught any'.

Intergenerational communication training was suggested to address the generational gap between educators and students. Collaboration among educators was deemed critical, with participants advocating for teamwork over individual efforts: 'Acting together as a team, not single teachers', can create more effective development paths for students.

Institutional support and knowledge-sharing were seen as vital for improving teaching practices: 'Do university employees share their knowledge on teaching methods for engineers? Are good practices in teaching engineers passed on and developed?' Collaborative aspects of teaching were stressed, as were the importance of educational collaborations among peers and informal exchanges during 'coffee breaks'. To adapt to rapid technological change, participants recommended creating a repository of teaching resources to support diverse and innovative approaches, enriching the learning experience and provide students with varied perspectives on complex topics.

4.2.3.3. Fostering students' competency development. Participants emphasise nurturing 'active and engaged students with an interest in shaping their education', suggesting that student motivation and involvement are key to fostering a dynamic learning environment. A critical component thereof is the concept of lifelong learning. A shared repository of examples and explanations for students across universities could deepen understanding and enhance the educational experience: 'Access for all students to bigger (shared between universities) collection of examples and different ways of explaining the solution would be great'.

An interdisciplinary approach to teaching is recommended, incorporating more courses focused on the development of professional skills alongside fundamental competencies such as applied mathematics, physics, computer science, and methods. Here, improving STEM education both in secondary schools and universities ought to ensure a strong foundation for future engineers. Evaluation processes within engineering programs should then evolve to assess not only standard task performance but also students' ability to propose innovative solutions and apply knowledge across sectors. Greater involvement in scientific research and opportunities for international mobility could enhance students' understanding, application of theoretical concepts and broaden their perspectives.

Lastly, a persistent question among participants was how to ensure that learning is retained. One participant posed, 'how can we make sure that the student's learning is not just for exam preparation … but is such long-lasting that university graduates have at least 30% of all of that present and can use it?'

4.2.3.4. Transforming the educational system. Addressing the myriad of issues related to workload, recognition for teaching, financial resources, and external pressures in engineering education requires change on the system level (see Section 4.2.1). Participants highlighted several key areas where reforms are necessary to create a more effective and supportive educational environment.

To rectify the imbalance between teaching and research, participants suggested providing grants specifically aimed at improving teaching programs through innovative techniques. Furthermore, participants advocated for a more balanced approach to career progression that values teaching effectiveness: 'To take in more consideration the teaching activities and their quality in career progression. Now it is almost zero'. Financial considerations also play a critical role towards change

relating to fair compensation and the potential for individual contracts that recognise the unique contributions of faculty members.

Additionally, there should be options for flexible contracts that fairly compensate experts who teach specialised topics but may not fit into traditional academic roles. Participants proposed the creation of a position that integrates industry experience with teaching responsibilities, such as an 'industrial and didactic worker'. This role would bridge the gap between theoretical education and practical application, enriching the learning experience with real-world engineering examples.

The dialogue between students and educators is also vital for effective learning. One participant highlighted the need for a reasonable student-to-teacher ratio to facilitate meaningful interaction. Reducing didactic responsibilities while providing strong incentives for improving teaching skills and methods was suggested to elevate educational standards.

5. Discussion and implications

The aim of this study was to explore the dynamics influencing teaching practices in European engineering education by examining the interplay of different structural conditions, such as national policies, institutional contexts, and individual attitudes towards teaching from educators' perspectives. For this purpose, engineering educators from five technical universities of four different European countries were taken as a case. Specifically, we investigated their perceptions of: (1) the impact of national political conditions on educational practices, (2) structural conditions affecting engineering education, and (3) how differences in these factors shape teaching practices.

To ground the subsequent discussion, Table 6 summarises the major themes identified in this study alongside targeted recommendations (see Section 4.2.3). These recommendations translate our analysis of participants' insights into policy and are linked with each other.

Overall, our results highlight significant challenges and opportunities in engineering education within different European universities. Moreover, our findings underline persistent structural, pedagogical, and cultural/political barriers that impact educational quality in engineering across countries.

Our findings closely align with those of Dart et al. (2024), who conducted interviews with engineering educators in the Australian higher education context. Similar to our results, their study highlights the importance of industry and engineering relevance in education, alongside a notable deficit in both knowledge of effective educational practices and access to appropriate educational training. Additionally, both studies highlight the misalignment between teaching and research as a persistent challenge, as well as the significant resource constraints – particularly a lack of time – that hinder educational innovation. They further identified collegial networks as a critical factor influencing teaching practices (see also Kjellberg et al. 2023), whereas our results point more strongly to the role of institutional support in shaping educators' experiences. We structure the remainder of the discussion starting from the individual level regarding educators' teaching practices and perspectives (5.1) to institutional (5.2), national (5.3), and European (5.4) implications (see Table 6). Section 5.2 focuses on institutional factors influencing educational quality, especially the relationship between teaching, research, and practice, and examines institutional challenges, thereby addressing RQ2. Section 5.3 expands to the national level, analysing how political frameworks and resource allocation shape teaching practices, addressing the implications of RQ1. Finally, Section 5.4 considers the European context, discussing cross-institutional collaboration and policy implications to align with RQ3.

5.1. Individual level – educators' teaching practices and motivation

As shown in Section 4, teaching methods vary between respondents of the different universities. Lecturing prevails as the most common teaching method, despite growing recognition of the benefits and the need for student-centred teaching and active learning approaches (Habbal et al. 2024; Hadgraft and Kolmos 2020). This pattern is most apparent at the Italian university Polimi, where participants use lectures most frequently, at the expense of other teaching methods. A

Table 6. Themes aligned with key recommendations on different levels. Items designated with a *are in alignment with recommendations from Dart et al., 2024. Square brackets indicate the section(s) related to each theme / recommendation.

Theme	Individual	Institutional	National	European
(Under-) Funding		Hire sufficient teaching staff* [**5, 5.2**]	Align European with national funding [**5.3, 5.4**]	
		Decouple funding for teaching activities from simple quantitative quality indicators* [**5.3**]		
Pressure to Produce Graduates		Shift evaluation metrics from quantity (e.g., graduation rates) to educational quality (e.g., graduates industry performance)*, and regularly assess indicators' effects [**5.2, 5.3**]		
Misalignment between Teaching vs. Research		Integrate educational quality into promotion criteria* [**5.2**]		
		Promote teaching-focused teaching roles and (hybrid) teaching roles bridging research and industry* [**5.2**]		
Bureaucracy		Streamline administrative processes to reduce time burdens and to foster flexibility regarding teaching experiments and collaboration [**5.2, 5.3, 5.4**]		
Workload and Time Constraints		Increase institutional support for teaching and engagement, including sufficient time for professional development* [**5.2, 5.4**]		
Student Preparedness and Motivation	Prepare students for real-world engineering practice [**5.1, 5.2**]		Strengthen secondary STEM education [**5.3**]	
Lack of Infrastructure for Teaching and Learning		Invest in modern teaching technologies and digital learning platforms using EUI alliances [**5.4**]		
		Ensure sufficient laboratory resources to facilitate hands-on learning [**5.3**]		
Teacher Qualifications and Practical Competence	Engage in professional development, regardless of seniority and experience [**5.1**]	Ensure pedagogical training for all teaching staff, both on tools and methods, particularly new educators* [**5.2, 5.3**]		Establish cross-national incentive systems via alliances [**5.3, 5.4**]
		Encourage partnerships between universities and industry to enhance faculty practical experience* [**5.2**]		
		Facilitate intergenerational learning to address technological and cultural gaps [**5.1**]		

possible explanation is that Polimi has the lowest staff to student ratio amongst all considered universities (see Table 1).

More generally, limited familiarity with innovative pedagogies, such as flipped classroom and peer learning, but also constructive alignment might limit the use of other teaching approaches. We found participants from all universities except Chalmers indicated a lack of knowledge thereof; and we found that participants from all universities including Chalmers desire to learn more about innovative teaching approaches. This suggests a need for targeted professional development, as noted in previous research (e.g. Dart et al. 2024; Felder, Brent, and Prince 2011; Kövesi et al. 2022; Lattuca, Bergom, and Knight 2014). There appears to be some institutional awareness of these issues, as a brief desk review of the teaching-related mission statements of the five universities included in this study shows that all explicitly highlight professional development and training as key objectives.

In a recent literature review on sustainability in engineering education in Europe, Gardelle (2025) found that educators are primarily driven by a personal sense of responsibility to respond to pressing societal and ecological challenges, rather than by institutional expectations or external policy mandates. Their motivation stems less from top-down directives and more from an intrinsic, citizen-oriented commitment to contributing to societal well-being (Gardelle 2025). Moreover, the review does not reveal specific national characteristics. This further supports our earlier findings based on the same data that intrinsic motivational factors – such as enjoyment in teaching and the

desire to positively impact students – are among the most significant motivational drivers of educators' engagement across ENHANCE (Winkens et al. 2024). While accreditation frameworks and institutional goals are not irrelevant, it is this strong sense of *purpose* that appears to be central (Biesta 2007). However, realising these ambitions often depends on structural and organisational conditions that can either enable or constrain meaningful change (see also Serafini et al. 2022; Wolff, Hattingh, and Smith 2025).

Interestingly, teaching duration does not correlate with a preference for particular methods, suggesting that professional development opportunities could benefit educators regardless of their level of experience. While in the survey, professors consider themselves to be better educated to effectively train engineers compared to non-professors, research also suggests that senior staff often do not perceive pedagogical training for themselves as necessary, compared to junior academics (Kövesi et al. 2022). Additionally, our results suggest that a strong disciplinary focus and resistance to change within engineering departments contribute to the persistence of traditional teaching methods. These findings align with prior literature on systemic obstacles to educational reform in engineering education (e.g. Graham 2012, 2018; Henderson, Beach, and Finkelstein 2011), which can deter instructors from adopting more effective pedagogical practices.

At the same time, the qualitative results reveal that some educators are satisfied with current teaching and perceive no need for change. However, research suggests that poor student outcomes – such as low grades or unfavourable evaluations – are often attributed to student deficiencies, such as incompetence or lack of motivation, rather than to the teaching methods employed (Felder, Brent, and Prince 2011).

However, educators' capacity and motivation to engage in educational change are shaped by the complex dynamics of their academic environment and the multiple levels of institutional influence they are embedded in (Cutler and Coso Strong 2023; Wolff, Hattingh, and Smith 2025,).

5.2. Institutional level – recognition, support and teaching conditions

As Habbal et al. (2024) and Graham (2018) highlight, educational leadership plays a critical role in creating and sustaining meaningful changes in teaching practices. Effective strategies require a balance of top-down and bottom-up approaches, where leaders support systemic coordination while empowering educators to experiment with innovative teaching approaches. Solely top-down directives risk disengagement, whereas purely bottom-up efforts often lack cohesion (Habbal et al. 2024). Piskadlo (2016) shows that faculty adoption of learner-centred teaching practices is influenced by institutional structures and policies, particularly those related to leadership, departmental configuration, funding, faculty development, infrastructure, and incentives. This aligns with our findings, which emphasise the need for institutional support to foster pedagogical innovation. Considering the high intrinsic motivation of university educators noted in Section 5.1, fostering unbureaucratic space for teaching and teaching experimentation is a promising approach for this. Other key institutional challenges to innovation and educational quality in engineering education include time constraints, and insufficient infrastructure, which align with findings frequently reported in the literature (e.g. Dart et al. 2024; Graham 2018; Henderson, Beach, and Finkelstein 2011). Among these, lack of time was perceived as the most significant hindrance.

Discrepancies in the valuation of teaching versus research remain a pervasive issue, echoing findings from previous studies (e.g. Graham 2018; Lattuca, Bergom, and Knight 2014; Pitt and Mewburn 2016; Smith and Walker 2024) and also a result of the *Teaching Cultures Survey* (Graham 2020, see Section 2). However, in our quantitative results, the mean value for the item 'Positive Career Impact' is in the medium range. Instead, in our thematic analysis it is evident that, across institutions, teaching is often not only undervalued, with educators reporting minimal career incentives or institutional support for pedagogical excellence, but also perceived as hindering an academic career, especially in Italy and Poland. This is worsened by the fact that in teaching-focused career pathways, employers often face ambiguity surrounding institutional expectations, scholarship

evaluation, and advancement criteria, highlighting the importance of robust institutional support (Smith and Walker 2024).

In general, academic career pathways are 'not perceived as rewarding teaching achievement' (Graham 2018, p. iii). Including transparent criteria on teaching in academic career evaluations is necessary, particularly if positions involve substantial teaching duties. In Sweden and Norway, systems to reward teaching and provide recognition for teaching excellence have been in place for more than 20 years. In a recent interview study by Førland and Roxå (2024), rewarded Norwegian educators pointed out that in many cases, they were willing to contribute more but felt hindered by a lack of institutional strategy for educational quality that makes use of their talents. Even if such strategies are in place, there are many challenges associated with evaluating teaching performance in a valid and meaningful way. As Biesta (2009) argues, the question of what constitutes good teaching cannot be reduced to technical indicators alone, since judgments about educational quality are inherently normative and tied to broader questions of purpose. Attempts to quantify teaching quality often fail to capture its complexity.

An institutional survey done by the EUA found that 98% of higher education institutions employ student feedback surveys as their indicator to assess teaching quality (Gaebel et al. 2018). However, these are influenced by 'racist, sexist and homophobic prejudices, and biases against disciplines and subject areas' (Heffernan 2021, 1). Even when suitable evaluation metrics exist, that does not imply that they inform decisions: Levander and Riis (2016) evaluated eleven years of professorial promotion data from Sweden, finding that many quality indicators had little effect on the final decisions, as had in fact many research indicators. They concluded that there is a 'resistance imbedded in the peer review system against external forces of change' (Levander and Riis 2016, 9). This problem does not apply to teaching only. Abramo, D'Angelo, and Rosati (2015, 11) found the main predictor for success in Italian academic careers to be 'the number of years that the candidate has belonged to the same university as the selection committee president', mirroring the accusations of malpractice raised by some participants from Polish universities. This is in line with our results that indicate some researchers prefer the status quo, and that institutional resistance to change is seen as a major barrier. At the same time, there may be a gap between policy documents and the lived reality of academics: Organization for Economic Co-operation and Development (OECD) survey data suggest that Italy is one of few countries with specified legal rules on teaching criteria in academic staff recruitment and appraisal (OECD 2024), yet our participants found little evidence thereof. Thus, universities must not only identify and acknowledge teaching quality, using indicators that go beyond graduation rates and student evaluations, they also have to put structures in place that utilise and foster educators' skills. These structures need to be regularly assessed, as academics may otherwise resort to 'creative compliance' to meet objectives in the face of institutional pressure, rather than pushing for actual innovation (Narayan 2020, 19).

Furthermore, the issue of integration of teaching and practice was raised repeatedly. This aligns with the often-reported lack of collaboration and integration of industry, i.e. engineering practice (e.g. Brunhaver et al. 2018; Dart et al. 2024; Trevelyan 2019). This is reflected, on the one hand, in shortcomings within engineering education itself regarding students' personal and competency development. On the other hand, it becomes evident in the fact that engineering students often transition into teaching roles without substantial practical experience in engineering practice and without formal training as educators (Borrego and Streveler 2015; Dart, Trad, and Blackmore 2021; Trevelyan 2019). As a result, there is frequently a lack of knowledge in both *engineering* and *education*. To address this issue, one proposition of our respondents was the introduction of an 'industrial and didactic worker' position to bridge the gap between theoretical education and practical application. Such positions already exist in some countries: for example, the 'professor of practice' title in the US is used to recruit industry professionals into university teaching positions. These positions are actively promoted by leading technical universities like MIT, Carnegie Mellon or Cornell. Similarly, India's 'National Education Policy 2020' (University Grants Commission n.d.) introduces a professor of practice title, funding such positions to bring real-world practices and experiences

into classrooms. These examples illustrate that the proposal is actionable. In line with this, Trevelyan (2019) argues for strong collaborations between HEIs, firms and governments to fully grasp engineering practice.

5.3. National level – policy frameworks, funding and education systems

Our findings underline the importance of considering national political as well as institutional contexts when implementing change strategies in higher education. Henderson, Beach, and Finkelstein (2011) proposed the *Four Categories of Change Strategies* model to classify approaches used to conceptualise or implement change in undergraduate STEM education. These strategies – disseminating curriculum and pedagogy, developing reflective teachers, enacting policy and developing shared visions – align with our results. Effective change strategies must account for individual beliefs, institutional complexities, and the long-term nature of interventions. However, as emphasised by previous research, understanding national and local variations is crucial for tailoring these strategies to specific contexts (e.g. Borrego and Henderson 2014; Finelli, Daly, and Richardson 2014; Gardelle et al. 2016; Wolff, Hattingh, and Smith 2025). For example, in some countries, such as Sweden, faculty development is compulsory, in others it is based on institutional decisions (European Commission n.d.; Kolmos, Hadgraft, and Holgaard 2016). This aligns with our decision to consider issues around Poland more closely as a specific theme, as this example illustrates how national policies and institutional structures shape barriers and opportunities for change.

The effectiveness of change strategies is influenced by the availability of resources and the broader policy environment in which universities operate. For example, universities in countries with lower funding opportunities, such as Poland and Italy (Ilieva et al. 2019), face significant challenges and barriers in fostering educational change, despite faculty interest. Moreover, it is known that university funding is frequently inadequate to support their expected leading role, in some cases investment in higher education is even decreasing despite rising student enrolment (Bennetot Pruvot, Estermann, and Kupriyanova 2020; European Commission 2022). When funding is limited, its allocation becomes even more important. Funding allocation may then lead to dissatisfaction, especially if policymakers and academics priorities differ, as for example in the case of engineering vs. theology in Poland. Notably, this applies to indicators for educational quality (see 5.2) as well. While the OECD reports that nationally, the use of educational quality indicators is widespread (OECD 2024), a survey of 27 of its member states indicates that by far the most frequently used educational quality criteria for funding allocation are enrolment and the number of degrees/credits awarded (Golden, Troy, and Weko 2021). Clearly, these criteria pose a risk for misalignment, as pointed out by our survey participants.

Teaching loads are generally determined at a level above individual universities. On the precise level and format, there is no comparable standard between countries. We compared teaching loads based on EU documentation *Eurydice*.[1] Although participants from Poland reported significantly higher teaching loads and reported spending more time than average time for teaching, this is not mirrored in the official data. Similarly, it is notable that tenured professors in Italy have the same working load as full-time teaching staff in Germany. Moreover, our findings show that participants from Polimi are significantly more satisfied with engineering education at their university compared to the others. At the same time, they criticise the status quo in terms of high student numbers, heavy teaching loads, and a general lack of appreciation for education. Moreover, some educators highlighted that those challenges are not confined to universities. In secondary education, student success is also frequently measured solely by graduation rates rather than knowledge acquisition, undermining the foundation of higher education. This broader educational culture ultimately calls into question the integrity and long-term value of academic degrees.

Respondents' suggestions reflect a collective desire for a comprehensive transformation of the educational system. Policy makers must acknowledge the tension between increasing quantity and quality of higher education. In their strategic framework for cooperation in education and

training (Council of the European Union 2021b), the EU sets targets such as reducing early school leaving to <9% and achieving >45% tertiary attainment among 25–34-year-olds by 2030. These goals imply a significant expansion of university access and, consequently, larger and more heterogeneous student populations. This quantitative ambition, while laudable in terms of access, must be critically examined considering what it demands from institutions and educators. Referring back to Biesta (2009), the increasing focus on measuring educational 'outcomes' – through international comparisons and performance indicators, such as OECD's Programme for International Student Assessment PISA – can shift attention away from deeper questions of educational purpose. When league tables become the dominant logic of evaluation, the risk emerges that education is reduced to a numbers game: who enrols more and who graduates more rather than asking *what kind of learning* is happening, and *for what ends*. If countries are to meet such targets responsibly, they must invest in corresponding structures and resources that support inclusive and purposeful education. Notably, these issues mask large national differences: For example, in Sweden, 47% of men and 62% of women aged 25–34 attain a tertiary qualification, compared to 24% of men and 37% of women in Italy (Council of the European Union 2021b).

Therefore, national frameworks must incentivise not only access to, but also excellence in teaching and sustainable funding for educational innovation (European Commission 2025). However, national labour laws and regulatory structures often limit the extent to which institutions can implement integrated incentive models across alliances like ENHANCE. This leads to fragmented incentive structures and alliances currently lacking the mandate to harmonise them, indicating a need for the establishment of a legal entity for an alliance to provide more flexibility (European Commission 2025). At the institutional level, universities should nevertheless foster cross-disciplinary collaboration and supportive environments for faculty development – in a way that it is 'exemplary in the way we are teaching students' (Habbal et al. 2024, 174). Systemic changes in engineering education requires a rebalancing of priorities between research output and educational engagement, fair compensation and recognition for educators, increasing resource allocation for innovative teaching methods, manageable student-teacher ratios, and stronger collaboration with industry through hybrid academic roles. These challenges and opportunities point toward the need for more coherent European-level strategies.

5.4. European level – policy alignment, alliances and collaboration

The normative orientation of the European University Alliances, including their commitment to shared values, democratic engagement, and sustainable development, demands a broader alignment of institutional strategies with European educational policy. Sustainability as a guiding principle is increasingly embedded therein, most notably through initiatives such as the European Green Deal and the European Sustainability Competence Framework (GreenComp) (Bianchi, Pisiotis, and Cabrera Giraldez 2022). Implementing this in practice requires structural transformation, cross-national collaboration, and the formulation of shared educational objectives that transcend institutional boundaries. European University Alliances like ENHANCE offer promising platforms for this endeavour – not only by fostering innovation and strategy alignment, but also by promoting mutual learning and moral reflexivity in engineering education (Fuchs, Cuevas-Garcia, and Bombaerts 2023). Research has shown that universities participating in one of the EUAs may enhance their capacity for innovation and their role in regional development by fostering closer collaborations among academia, industry, government, and civil society (European Commission 2025; Zenkienė and Leišytė 2024). This can be facilitated by close cooperation with existing research networks, such as, in Europe, SEFI as the largest network dealing with engineering education research, aimed at 'bringing relevant stakeholders together through the sharing of ideas, good practices, common goals, and experiences' (SEFI 2024).

However, to scale such transformations across Europe, structural support and long-term financial stability are crucial. Otherwise, alliances may suffer from a lack of incentives for academics to become

partake in a sustained manner, especially since time constraints rather than lack of awareness are perceived as the primary barrier to engagement by both academic and administrative staff (European Commission 2025). As highlighted by the ENHANCE Alliance, current funding models for EUAs are often short-term and fragmented. To fully realise their potential, alliances require reliable, long-term core funding that supports both their strategic development and the operationalisation of joint structures. This includes sustained co-funding at national and regional levels as well as improved coordination between European and national policy agendas (ENHANCE 2024; European Commission 2025). Furthermore, leveraging alliances like ENHANCE to facilitate knowledge exchange and cooperation among teachers, industry and research, to offer (digital) teaching infrastructure and to share best practices for teaching could help bridge institutional and national disparities. One example is the ENHANCE Innovative Learning Campus,[2] a collaborative platform that includes offerings from the member universities to one another, such as training for educators, students and administrative professionals. Moreover, the Toolkit for Academics[3] aims to support and guide educators in creating and implementing learning offers, and the Certificate in Higher Education Teaching (CHET)[4] offers mutually recognised certification of professional development activities.

In summary, alliances such as ENHANCE can serve as accelerators of transformation – provided that policy frameworks and funding mechanisms acknowledge and support their long-term role in shaping a socially and ecologically responsive higher education system. Yet, the success of European-level strategies ultimately depends on national and institutional willingness and capacity to implement aligned reforms. Bridging this implementation gap will be key to advancing sustainable change in engineering education.

5.5. Limitations and further research

This study has several limitations. First, reliance on self-reported data may introduce subjective biases, including social desirability (Nederhof 1985) and selection biases (Bethlehem 2010). Varying interpretations of terms like 'problem-based' or 'experiential learning' may also affect response comparability. Future research should complement survey data with qualitative interviews to deepen insights into educators' perspectives and contextual dynamics. While this study is focused on educators' perspectives, analysing governance documents from universities and national education systems could reveal how policies are implemented in practice. Second, our sample was skewed toward professors (around 85%), limiting comparisons across seniority levels. Third, voluntary participation and differing institutional procedures regarding dissemination yielded responses from only five of the ten ENHANCE universities, spanning four countries. Fourth, for Chalmers, the sample size was too small for in depth quantitative analysis. And fifth, the timing of the survey – coinciding with the Polish elections in October 2023 – may have influenced responses from Poland.

Moreover, our case study focuses on the ENHANCE alliance, whose member universities committed themselves to a shared vision for engineering education in Europe. These universities are leading technical institutions and are often among the largest in their respective countries. However, this sample limits the transferability of findings to smaller or less research-intensive HEIs, or those without a technical focus. Future research should include a broader institutional spectrum to assess how teaching practices vary across different types of HEIs and disciplines. National differences were evident, but educators' attitudes and perceptions showed cross-national similarities. Whether these reflect broader trends in engineering or are alliance-specific remains an open question. Similarly, variations within countries warrant further exploration. By exploring a broader spectrum of contexts, future research could provide a more comprehensive understanding of how national and institutional factors intersect in engineering education. At the same time, however, our results show large overlaps with the findings from Dart et al. (2024), who focused on engineering educators in Australia using a different methodological approach. But both works focus on Western countries and different narratives may emerge in other global contexts (see, e.g. Wolff, Hattingh, and Smith 2025).

As we saw in the linear regression, across the participating universities, the items do not capture relevant factors equally well, specifically regarding RWTH. This may be an indicator that the survey design, conducted by researchers affiliated with RWTH, Chalmers and NTNU, may have introduced biases. Additionally, free-text responses pointed to overlooked themes, such as salaries and digital infrastructure. Future instruments should incorporate these aspects and involve more diverse academic systems in their development.

Finally, while this study offers valuable insights, it does not address the longitudinal impact of EUI initiatives on educational quality and student outcomes, as the initiative is still in its early stages (European Commission 2025). Despite these limitations, this study provides a timely contribution to understanding how structural conditions shape teaching in engineering education and lays the groundwork for future efforts to build more sustainable, aligned, and purposeful systems across Europe and beyond.

Notes

1. Italy requires at least 250h (non-definite) and 540h (tenured) teaching hours per year for professors. Germany requires 8h per week for full professors, and up to 16h per week for full-time teaching staff. Assuming 30 semester weeks, this implies 240–580h of teaching per year. In Poland, lecturers have to do at most 240h of teaching per year for most staff, 360h for teaching staff, and 540h for 'instructors'. We did not find general information on required teaching hours for Sweden, but the example of Uppsala University shows a more complex system. Here, only a 40h work week is postulated and different teaching tasks are weighted. Teaching hours range from a target of 250h per year for professors to 340h per year for lecturers. Lecturers can reduce their teaching load by acquiring extra funding, up to a lower bound 100h per year (Bastidas 2023).
2. ENHANCE Innovative Learning Campus: https://ilc.enhanceuniversity.eu/
3. ENHANCE Toolkit for Academics: https://enhanceuniversity.eu/get-involved-staff/toolkit-for-academics/
4. ENHANCE Certificate in Higher Education Teaching (CHET): https://enhanceuniversity.eu/enhance-alliance-offer-a-certificate-in-higher-education/

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Data availability statement

We publicly provide all information on the survey and a subset of the results publicly via https://doi.org/10.5281/zenodo.14536200. To ensure anonymity, for the public version of the results, we removed the columns containing data on personal information regarding gender (D002), employment duration (D004), permanent position (D005), leadership positions (D006), disciplines (D007/8), teaching field (T005), teaching obligation (T006), teaching duration (T004) and all free-text fields.

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Appendix

Questionnaire

Item	Abbreviation
Demographics	
University	
Gender	
Employment Status	
Employment Duration	
Permanent Position	
Teaching and Education	
Currently Engaged in teaching	
Extent engaged	
Duration Teaching	
Disciplines Teaching	
Teaching Obligation	
Actual Teaching extent	
Teaching Methods *Which of the following teaching and learning methods/approaches do you use? [always – often – sometimes – seldom – never – do not know the method/approach]*	
Problem/project-based learning	*P*(j)BL
Challenge-based learning	CBL
Lectures	Lecture
Case-based learning	Case L
Collaborative learning	Coll. L
Flipped Classroom	Flipp. C
Exploratory learning	Expl. L
Peer learning	Peer L
Experiential learning	Expi. L
Constructive Alignment *Please indicate how much you agree with the following statements. [strongly agree – agree – neither/nor – disagree – strongly disagree]*	
I am familiar with the concept of constructive alignment.	CA Fam.
I apply constructive alignment in the design of my teaching.	CA Appli.
I would like to know more about the above teaching and learning methods/approaches.	Interest
Attitudes towards teaching and education *Please indicate how much you agree with the following statements. [strongly agree – agree – neither/nor – disagree – strongly disagree]*	
Overall, I am satisfied with the engineering education at my university.	EE Satisfaction
I feel I am sufficiently trained to educate engineers well.	EE Training
One does not need additional pedagogical training to teach well, if one is an expert in one's field.	No Pedagogic
I am committed to educate engineers well.	EE Commitment
My colleagues are committed to educate engineers well.	EE Peer Commitment
My university is committed to educate engineers well.	EE Uni Commitment
I would like my university to have a stronger focus on improving engineering education.	EE Focus Wish
In general, making an educational change requires taking initiative by students and teachers (bottom up).	Bottom-Up
In general, making an educational change requires taking initiative by faculty and university management (top down).	Top-Down
Spending time on teaching has a positive impact on my career progression.	Positive Career Impact
Spending time on teaching has a negative impact on my career progression.	Negative Career Impact
I am teaching only because it is one of my obligatory tasks.	Obligatory Teaching
Motivation Aspects (not part of this paper, we refer to Winkens et al. 2024) *Please indicate to what extent you perceive the following aspects as motivating factors for engaging in engineering education. [strongly agree – agree – neither/nor – disagree – strongly disagree – not applicable]*	
Recognition from my colleagues	
Recognition from my line manager	
Recognition from my department/faculty	

(*Continued*)

Continued.

Item	Abbreviation
Demographics	
Recognition from university senior management	
Recognition from my research community	
Funding opportunities	
The university supports an educational change	
Combining teaching and research	
Freedom to determine what and how to teach	
Motivation of the students	
The pleasure I get from teaching	
Responsibility for students' skills development	
The desire to positively impact students' skills development	
The desire to positively impact students' future engineering career	
To apply best practice examples in my own teaching	
To educate students with newest teaching methods/approaches	
To bring actual research to the students	
To motivate and inspire students for the subjects of research	
To exchange with younger generations	
Hindering Aspects (not part of this paper, we refer to Winkens et al. 2024)	
Please indicate to what extent you perceive the following aspects as hindering factors for engaging in engineering education. [strongly agree – agree – neither/nor – disagree – strongly disagree – not applicable]	
Lack of recognition from my colleagues	
Lack of recognition from my line manager	
Lack of recognition from my department/faculty	
Lack of recognition from university senior management	
Lack of recognition from my research community	
Lack of funding opportunities	
Lack of time	
Lack of climate for an educational change on my university	
Difficulties in combining teaching and research	
Freedom to determine what and how to teach	
Lack of students´ motivation	
Lack of personal motivation	
Potential failure in teaching students	
Lack of confidence in my teaching skills	
Lack of practice examples from teaching to apply myself	
Political Aspects	
Please indicate how much you agree with the following statements regarding political aspects. [strongly agree – agree – neither/nor – disagree – strongly disagree – I don't know]	
In my country, there are funding opportunities to improve engineering education.	National Funding
In my university, there are funding opportunities to improve engineering education.	Uni Funding
In my faculty, there are funding opportunities to improve engineering education.	Faculty Funding
The national political framework in my country enables me to improve my teaching.	Enabling Policies
The national political framework in my country prevents me to improve my teaching.	Preventing Policies