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Sustainability in engineering education: an editorial and interpretive synthesis

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ABSTRACT

This editorial provides an introduction to and interpretive synthesis of the seventeen contributions to the European Journal of Engineering Education special issue on Sustainability in Engineering Education, and the current state, emerging trends, and future directions of the field. The special issue contributions indicate that sustainability in engineering education is moving beyond early add-on approaches towards broader curricular integration, yet transformative ambitions remain only partially realised and unevenly enacted across institutional, disciplinary, and national contexts. These insights are complemented by two additional perspectives: a reflective insider account of current trends at one European university and a critical challenge to dominant European viewpoints through South African scholarship on transformation and decolonisation. Beyond further curricular integration, the next phase of sustainability in engineering education is argued to depend on enhanced institutional reflexivity, epistemic plurality, and critical engagement with the purposes, assumptions, and societal responsibilities of engineering education and engineers.

KEYWORDS

Sustainability in engineering education; engineering education; education for sustainable development; integration; transformation; decolonisation

Introduction

This editorial introduces and synthesises the 17 contributions to a special issue of the European Journal of Engineering Education (EJEE) that collectively capture a field in transition. We have chosen 'sustainability in engineering education' as the theme of the special issue, intended as an open and inclusive perspective on the evolving relationship between sustainability and engineering education. Alternative notions could, for example, have been 'engineering education for sustainable development' (Azapagic et al. 2005; Mathebula 2018; Mulder, Bretelle-Desmazieres, and Foxley 2008) or 'engineering education for the end of the world as we know it' (Stein et al. 2022). We acknowledge that sustainability, sustainable development, and transformation are complex, ambiguous, and contested concepts (e.g. Mebratu 1998; Ruggerio 2021). Rather than seeking to resolve these ambiguities, we engage with how they are currently interpreted and operationalised in the context of engineering education while recognising the potential for further nuance, reconceptualisation, and reimagination.

The special issue papers collectively cover multiple dimensions, ranging from international frameworks and university policies to pedagogical approaches and individual students' emotional responses to learning. Each contribution stands on its own, while this editorial provides an interpretive synthesis and reflects on the current state, emerging trends, and future directions. The editorial

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is structured as follows: First, the broader landscape where the special issue is situated is briefly sketched. Then the 17 special issue papers are presented under three themes: (1) the messy realities of educational and institutional change; (2) the purposes, processes, and pains of engineering education; and (3) experiential, cooperative and extra-curricular learning. Inherent tensions, gaps, and limitations are identified. Recognising the aims and scope of EJEE, that it is 'a European journal with global readership and authorship', and the predominantly European perspective represented in this special issue, we broaden the discussion through two complementary viewpoints: a reflective insider perspective from one specific European university of technology and a critical challenge to dominant European perspectives from a South African scholarly viewpoint. Finally, a concluding synthesis and look ahead.

Landscape

A comprehensive review of the international landscape of sustainability in engineering education is beyond the scope of this special issue editorial. However, here we sketch some perspectives of the historical background and context for the special issue. One starting point for understanding the landscape of engineering education is provided in the special issue contribution by Gardelle (2025). In Gardelle's paper it is described how engineers in Europe in the eighteenth and nineteenth centuries were trained as servants of society to drive national infrastructure and development. As exemplified through France's Grande Écoles, humanities and civic values were part of the curriculum at the time. Through the twentieth century, accelerating industrialisation, the rise of private enterprise, and the emergence of consumer society shifted the focus of engineering education towards disciplinary specialisation, technical and organisational skills, and market-driven efficiency. In the twenty-first century, characterised by even more accelerating technological development, geopolitical instabilities and socio-ecological predicaments, engineering education now grapples with how to equip students with specialised technical knowledge and skills, as well as broader and integrated knowledge, transferable skills, social and ethical values, as well as capabilities to navigate socio-ecological complexities and address wicked problems. As expressed in the special issue contribution by Cuevas-Garcia (2025), universities now 'need to constantly juggle between different versions of their future to remain competitive and to deliver on the promise of training the next generation of professionals'. Yet another complexifying factor is the increasing awareness of the ambiguous and contested roles that engineers, scientists and technology have played (Höppener 2016; Lucena and Schneider 2008; Mathebula 2018).

The emergence of engineering education for sustainable development (EESD) is briefly overviewed in the special issue contribution by Menon et al. (2025), starting from the broad establishments of 'sustainable development' (SD) as a concept in the Brundtland Report in 1987 and 'education for sustainable development' (ESD) in Agenda 21 during the 1992 UN Rio Summit, through various national and international policies and initiatives such as UN's 2030 Agenda and the sustainable development goals (SDGs). In addition to the milestones indicated by Menon et al. (2025), the establishment of the EESD conference in 2002 also deserves mention (Thürer et al. 2018). The development in this field is partly reflected in the EJEE, for example, in Azapagic, Perdan, and Shallcross (2005) and in the previous special issue on this theme (Mulder, Bretelle-Desmazieres, and Foxley 2008). We consider sustainability in engineering education in the present special issue, and through Gardelle's (2025) review of 41 sustainability-related papers published in the EJEE during the period between the two special issues. Some of the key findings in Gardelle's comprehensive analysis, which was consciously limited to papers with at least one author affiliated with a European institution, are the following:

- Authors are mainly coming from engineering science rather than educational science backgrounds and mostly describe themselves as acting from personal, citizen-driven conviction rather than from institutional mandates or industry demands.
- The field is characterised by a positivist, 'what works' orientation, focused on solutions and standardised procedures rather than on critical or conceptual understanding. The majority of the papers reviewed in Gardelle (2025) are categorised as surveys (60%), followed by case reports (30%), whereas purely theoretical papers were rare (10%).
- Three pedagogical approaches recur and co-occur across the reviewed papers: active, student-centred pedagogy; experiential/problem-based learning; and integrative or holistic (interdisciplinary) approaches.
- In the notions of Sterling (2004) and Kolmos et al. (2016), add-on initiatives are observed to be rare among the reviewed papers; integration is widespread, whereas transformation remains aspirational. Persistent gaps are observed between transformative ambitions and actual implementations, explained by curricular rigidity, scheduling constraints, and limited institutional support and resources. Integrative and transformative practices are, however, observed to be increasing, and a shift is concluded to be underway in how the role of engineers is imagined: away from industrial productivity and towards addressing broad societal challenges.
- The initiatives reflected in the papers reviewed by Gardelle are predominantly framed at a generic, global scale, whereas locally or regionally specific sustainability needs are rarely addressed, and global South perspectives are largely absent.

The last point is important to emphasise because it is a noticeable limitation in this special issue as well. This limitation is addressed later within this editorial in the section titled: 'Challenging dominant perspectives with views from the South'. This section does two important things for this special issue. Firstly, while appreciating all the papers in this special issue, we push back on some ideas that emerge from their findings. Secondly, by bringing in 'views from the South' we engage mostly with South African literature on higher education transformation and decolonisation, shedding light on ways in which global South scholarship enriches the landscape. While this section challenges European perspectives, yet another section included in this editorial provides reflections on the current trends at one specific European university.

Special issue contributions

In response to the call for proposals to this special issue, a total of 48 extended abstracts were submitted. After a review process by the guest editorial board, 31 were invited to submit full manuscripts. Of these, 22 responded, and yet 2 more full manuscripts were submitted without preceding abstract submission. Through the double-blind review process, where two or three external reviewers engaged with each manuscript, 17 were accepted, while 2 were withdrawn by the authors and 5 were rejected or recommended for consideration in a standard issue. Table 1 is an overview of the 17 included papers, structured in their order of appearance in the special issue and under three themes. Not surprisingly, several of the patterns identified by Gardelle (2025) and outlined in the previous section can also be found among the special issue papers, while several new perspectives also appear, as elaborated in the following sub-sections.

Theme 1: the messy realities of educational and institutional change

The six special issue contributions that we present under this theme consider opportunities, drivers, and barriers in change processes on programme and university levels in different national, and in two cases cross-national, contexts. Bolstad, Verhulst, and Henriksen (2025) present a case study that explores educators' perspectives on integrating sustainability in an electrical engineering pro-

Table 1. Special issue contributions (where 'geographical context' refers to the locations of universities authors are affiliated with and in parenthesis additional contexts engaged with).

Paper	Title	Type	Geographical context
Review of the preceding 15 years			
Gardelle (2025)	Sustainability in engineering education in Europe over the last 15 years: visions and tendencies among educators as revealed by a literature review.	Literature Review/Theoretical	France
Theme 1: The messy realities of educational and institutional change			
Bolstad, Verhulst, and Henriksen(2025)	Educators' perspective on integrating sustainability in higher engineering education: a case study within an electronic engineering study programme	Qualitative case study	Norway
Gutierrez-Bucheli et al. (2025)	Educational responses to sustainability in engineering programs: practices and prospects.	Instrumental case study	Australia
Cuevas-Garcia (2025)	Sustainability and patchwork transformations in engineering education.	Autoethnographic study	Germany
Peters and Rosén (2025)	Pain and Pleasure in working with sustainability and transformation at a technical university: An exploration of the role of educational developers through collaborative autoethnography.	Collaborative autoethnographic study	Sweden
Menon et al. (2025)	Understanding instructor decision-making in engineering education for sustainable development: a comparison of institutions in Denmark and the United States.	Comparative case study	USA & South Africa (& Denmark)
Högfeldt (2026)	Expansive change in higher education: a cross-case analysis of engineering education leaders implementing the sustainability agenda.	Cross-case analysis	Sweden (& Tanzania)
Theme 2: The purposes, processes, and pains of engineering education			
Dahlin (2026)	Aligning engineering education for sustainable development with what industry needs to drive the transformation.	Qualitative survey	UK (& Sweden)
Karvinen et al. (2026)	Working life relevance of sustainability-oriented engineering education and graduates' influencing possibilities – insights from Finnish employers.	Mixed-methods case study	Finland
Appelhans et al. (2025)	Towards sustainable pathways in engineering education: examining structural factors and individual agency through student narratives.	Qualitative study	USA (& West Africa)
Lucena et al. (2026)	Bringing it down from the ivory tower: translating Engineering -for-Community-Development (ECD) graduate education and research into community engagement and undergraduate student learning.	Collaborative autoethnographic study	USA (& Argentina, Colombia)
Nießner and Rosén (2025)	Do not listen to students' voices: give them the power to transform!	Qualitative study	Sweden (& Austria, Germany, Japan, Kenya, Singapore)
Sterner et al. (2026)	'Out into space?'- Engineering students' understanding of the carbon cycle and challenges they face while solving atmospheric CO_2accumulation tasks.	Qualitative study	Sweden
Holmén and Lönngren (2025)	Expanding sustainability learning in engineering education through emotional scaffolding.	Qualitative study	Sweden
Theme 3: Experiential, cooperative, and extra-curricular learning			
Mohd-Yusof et al. (2026)	Beyond awareness: instilling environmental sustainability knowledge through cooperative problem-based learning.	Longitudinal qualitative case study	USA & Malaysia
Hitt et al. (2025)	Developing sustainability competencies through extra-curricular interdisciplinary challenges.	Evaluative case study	UK
Sundman et al. (2025)	Experiential learning for sustainability: a systematic review and research agenda for engineering education.	Systematic Review	Finland

gramme at a Norwegian university. Similarly, Gutierrez-Bucheli et al. (2025) study educators' intentions and priorities, and also students' learning experiences, in a civil engineering programme at an Australian university. As in the call for this special issue, both these studies apply levels-of-change models drawing from Sterling (2004) and Kolmos, Hadgraft, and Holgaard (2016) to distinguish superficial add-on responses from deeper integration and, ultimately, rebuilding and transformation, and assess how far change has progressed. Cuevas-Garcia (2025) and Peters and Rosén (2025) use autoethnography for exploring sustainability integration and transformations at two technical

universities, respectively in Germany and Sweden. Menon et al. (2025) present a comparative case study of universities in Denmark and the US, while Högfeldt (2026) makes a cross-case analysis of three multi-year studies conducted in Nordic and Tanzanian higher education contexts.

Bolstad et al. (2025) and Högfeldt (2026) both locate their analyses in the 'in-between' space where institutional mandates meet everyday teaching practice, revealing persistent tensions between policy intent and educator engagement. Along the same line, Gutierrez-Bucheli et al. (2025) emphasise the gap between the intended curriculum – what appears in formal documents – and the implemented and experienced curricula – what actually happens in the classroom and what students take away from it. Cuevas-Garcia (2025) extends this line of thinking conceptually, introducing the idea of 'patchwork transformations' to capture how sustainability, entrepreneurship, employability, internationalisation and other reform agendas overlap, interact, and conflict within the same institution.

Several of these papers concern the agents who carry this work forward, and the conditions that enable or constrain them. Menon et al. (2025) offer a comparative perspective, showing that individual commitment drives sustainability engagement in the US context, whereas in settings such as Denmark, institutional and national conditions make such engagement normative rather than a matter of personal initiative. Bolstad et al. (2025) identify concrete internal barriers, such as lack of time, motivation, and competence, that prevent educators from acting on their own sustainability commitments. Högfeldt (2026) highlights the role of academic middle leaders, such as programme directors, who must build informal legitimacy to mobilise colleagues across rigid departmental boundaries and research-oriented reward systems. Peters and Rosén (2025) add an affective and reflexive dimension when exploring the role of educational developers, and the complex landscape of personal, interpersonal, organisational, disciplinary, cultural, and other dimensions and tensions that they have to navigate. The potential role of students as educational change agents is considered in one of the cases in Högfeldt (2026), and also in Appelhans et al. (2025) and Nießner and Rosén (2025), which are presented under the second theme.

Together, these papers highlight that universities are highly heterogeneous entities with multiple, sometimes incompatible, goals. These studies further emphasise that sustainability in engineering education is not a linear implementation process but an ongoing, often uncomfortable negotiation between individual agency and structural constraints, between institutional vision and disciplinary autonomy, and between the promise of transformation and the practical realities and heavy weight of established practice. By foregrounding the educators, middle leaders, and educational developers who mediate this negotiation, these papers together offer a comprehensive map of the drivers and barriers that will determine whether engineering education can move from superficial add-ons and patchwork adaptation towards deeper integration and transformation.

Theme 2: the purposes, processes, and pains of engineering education

The seven contributions that we have associated with this theme consider various aspects of the purpose of engineering education and expectations from and needs of society, but also processes of students' identity formation, learning and growth and the emotions that emerge from engaging in problem-solving endeavours.

Dahlin (2026) and Karvinen et al. (2026) both investigate the evolving relationship between engineering education and the needs and requirements of employers, the former through a qualitative survey involving engineering programme directors at Swedish universities and sustainability managers at Swedish companies, the latter through a mixed-methods case study engaging with Finnish employers. Through the survey and the lens of a Sustainability Maturity Level framework, Dahlin (2026) shows that industry is a diverse landscape where expectations vary significantly depending on a company's sustainability orientation. Observing that only companies on higher maturity levels prioritise sustainability competencies such as systems thinking and value creation across stake-

holders. Karvinen et al. (2026) complement this by examining how sustainability competencies translate into actual agency and 'influencing possibilities' at work, observing that although employers expect graduates to apply sustainability independently, early-career engineers' real influence is often constrained by organisational culture, hierarchy, and project parameters. Together, these two papers reveal a tension between meeting current industry needs and cultivating key competencies and critical mindset to challenge existing business logics, suggesting that aligning engineering education with societal needs requires not just curricular mapping, but deeper academia-industry collaboration to build shared vision and support agency.

The works of Appelhans et al. (2025), Lucena et al. (2026), and Nießner and Rosén (2025) are related in multiple ways, for example in that they engage with students (respectively through narratives, autoethnographies, and focus group workshops) across geographical contexts. Appelhans et al. (2025) and Lucena et al. (2026) are both conducted at universities in the US. In these two studies, the research participants included domestic students and, respectively, students from West Africa and Latin America. Nießner and Rosén's (2025) work is conducted at a Swedish university, involving students from North and Central Europe, East Asia, and East Africa. Different conceptual frameworks are used to interpret the data across these papers. For instance, Appelhans et al. (2025) utilise Amartya Sen's capability approach to reveal how institutional structures and systemic inequalities affect individual motivation and agency to study engineering and become an agent of sustainability in society, especially for black students. Their analysis of student narratives demonstrates that commitment to sustainability is often driven by childhood experiences and personal visions of a good life, yet these interests are frequently stifled by a lack of institutional activation and support. Lucena et al. (2026) conceptualise this as an ontological formation where students' 'entire being is at stake', requiring them to critically connect their personal histories, including their location, knowledge, and desires, with their engineering work and research to overcome deeply socialised norms like depoliticisation and meritocracy. Nießner and Rosén (2025) conceptualise students' experiences and ideas of sustainability education in terms of Sterling's levels-of-change and Biesta's concepts of qualification, socialisation, and subjectification, advocating for transition towards an emancipatory paradigm where students are invited and encouraged to take part in educational development and transformation. By shifting the focus from narrow technical training to a holistic professional and personal formation, these authors collectively offer a vision for an engineering education that empowers graduates not just as instrumental problem-solvers, but to actively re-imagine and transform educational and societal futures.

Sterner et al. (2026) and Holmén and Lönngren (2025) are closely related through their shared focus on the affective dimensions of students' capabilities to navigate complexity and wicked sustainability issues. Both focus on Swedish universities. Sterner et al. (2026) study engineering-mathematics students' understanding of atmospheric CO_2 accumulation. The study reveals that in addition to cognitive challenges such as misconceptions about carbon-cycle components and physics/mass-balances, and metacognitive gaps such as poor self-monitoring against given data, students also experience challenges related to climate beliefs, attitudes, and emotions that affect problem-solving processes. Holmén and Lönngren (2025) study interactions of engineering students in group work on wicked sustainability issues, identifying educational challenges that trigger expression of a wide range of emotions, which might either hinder or enhance learning. While Sterner et al. (2026) provide rich supplementary material that might assist further research as well as practice, Holmén and Lönngren (2025) provide a pedagogical strategy by theorising and testing the concept of Emotional Scaffolding. Together these two papers challenge the traditional image of engineering education as a purely rational enterprise and suggest that emotions, values, and affective dimensions are central to teaching and learning, problem-solving, and change processes in contexts of sustainability and transformations. In addition to these two papers, nearly every paper in the special issue engages with affective aspects to some degree, recognising that the sustainability transition is as much a social, human and emotional challenge as it is a technical one.

Theme 3: experiential, cooperative, and extra-curricular learning

The third recurring theme that we highlight across the special issue considers experiential teaching and learning approaches, such as cooperative, problem-based, project-based, challenge-based, and challenge-driven teaching and learning, as well as learning that occurs outside the formal curriculum. While several of the papers presented under the two preceding themes consider such approaches to some extent (e.g. Gutierrez-Bucheli et al. 2025; Högfeldt 2026; Lucena et al. 2026), including community-engaged approaches, three papers are highlighted here to bring these approaches into focus.

Mohd-Yusof et al. (2026) present a longitudinal qualitative study of the implementation of Cooperative Problem-Based Learning (CPBL) in a mandatory Introduction to Engineering course in the first year of a chemical engineering programme at a university in Malaysia. Situated in the UK, Hitt et al. (2025) present a case study of an interdisciplinary challenge-based learning experience in the form of an industry-led extra-curricular design competition. Together, these two papers illustrate how collaborative learning environments and authentic, real-world sustainability challenges, whether embedded within the curriculum or offered as extra-curricular experiences, can develop and connect sustainability knowledge, professional competencies, and authentic engineering practice.

Conducted at a Finnish university, the third paper under this theme, Sundman et al. (2025), presents a systematic literature review of 83 empirical studies concentrated in North American (46%), European (29%), and Asian (18%) contexts, published between 2003 and 2023. A rapidly expanding landscape is identified in which experiential learning, and its various alternatives, has become a dominant approach for integrating sustainability into engineering education. It is, however, also observed that research remains fragmented, that implementations are concentrated in elective and disciplinary contexts, and that comparatively little attention is given to transformative learning. Based on this, a nine-point research agenda is proposed calling for more balanced research, stronger theoretical integration, longitudinal studies, richer assessment methods, and deeper investigation of transformative learning processes and outcomes.

Emerging tensions and gaps

Although not a theme per se, a number of tensions recurring across the special issue papers deserve special mention. One such tension is between technocentrism versus socio-technical transformation. Engineering is positioned, on the one hand, as necessary for solutions and, on the other hand, as a source of sustainability problems. Appelhans et al. (2025), Bolstad et al. (2025), and Lucena et al.(2026) are among the papers where these tensions are present. There are also tensions found between global frameworks versus local/contextual interpretations. SDGs, ESD, and other global frameworks provide common language, but several papers stress the need for translating sustainability into specific national, institutional, cultural, professional, or community contexts (e.g. Cuevas-Garcia 2025 Lucena et al. 2026; Menon et al. 2025). Another tension is between planned transformation versus emergent change, and closely related to that, between institutional strategy versus local practice. Transformation is often called for as systemic and intentional, yet several papers repeatedly show change as fragmented, negotiated, partial, painful, and as 'patchwork' (e.g. Cuevas-Garcia 2025; Högfeldt 2026; Peters and Rosén 2025). Yet another tension is between industry alignment versus proactive societal leadership, i.e. whether universities and engineering education should primarily respond to industry needs or contribute to redefining what industry and society ought to pursue (e.g. Dahlin 2026; Hitt et al. 2025; Karvinen et al. 2026). Closely related to this is the tension between competence-oriented integration versus transformative education. While several papers treat sustainability as competence to be developed, others question whether education should train students *for* predefined sustainability goals or open democratic contestation about what sustainability means and how engineering and societal futures might be re-imagined (e.g.

Bolstad et al. 2025; Gutierrez-Bucheli et al. 2025; Nießner and Rosén 2025). There is also a tension highlighted between individual agency versus structural conditions, where students, educators, educational developers, and graduates are framed as change agents, while their agency is shown to be constrained by curricula, institutions, workplaces, norms, and power relations (e.g. Appelhans et al. 2025; Högfeldt 2026; Nießner and Rosén 2025; Peters and Rosén 2025). Yet another tension is between cognitive knowledge versus affective, relational and existential learning (e.g. Holmén and Lönngren 2025; Sterner et al. 2026; Sundman et al. 2025).

Naturally, since there are only 17 papers, there are a number of gaps and important areas that are given limited or no attention among the special issue contributions. As already highlighted, the contributions to this special issue are predominantly European, drawing on Global North perspectives, while perspectives from the Global South remain marginal. There is further a limited range of alternative theories or approaches as conceptual or theoretical frameworks for sustainability in engineering education, e.g. de-growth, postcolonial, and/or feminist theories, etc. Most studies are single-course, single-programme, or single-institution, and what enables or inhibits scaling and transfer is given limited treatment. Karvinen et al. offer a beginning, but the long-term formation of sustainability-oriented engineering identity and agency remains understudied. Yet another important area that is not considered is assessment: how sustainability competencies might be evaluated in ways that match the transformative ambitions described.

We will elaborate on some of these tensions and gaps in the following two sections and in the concluding synthesis and look-ahead section.

Personal reflections on a specific European university

Any description of education for sustainable development (ESD) is inevitably shaped by the context in which it is situated. Rather than seeking to provide a representative picture of ESD in higher education more broadly, this section offers an insider perspective from within one European university of technology. Read alongside contributions that provide perspectives on sustainability in engineering education from other geographical and institutional contexts, this perspective can contribute a richer and grounded account of what is observable within this landscape in practice.

These reflections illustrate how some of the tensions identified in the preceding section are manifested within a particular institutional context, including those between strategic ambitions and educational practice, between incremental improvement and more fundamental transformation, and between responding to external expectations and actively contributing to shaping societal futures. They also provide insight into issues that received more limited attention in the special issue papers, including the challenge of sustaining momentum over time.

In this sense, experiences from a single institution can serve not only as a local case but also as a basis for reflection, discussion, and mutual learning across contexts. For these reasons, this part of the editorial will be of particular interest to university leaders, managers, and fellow sustainability practitioners.

I, Ulrika Lundqvist, one of the guest editors of this special issue, coming from engineering science, write from the position of a practitioner as a long-time teacher in sustainability, and later also in ethics and EDI (equity, diversity and inclusion), at Chalmers University of Technology. Over the years, I have also had extensive experience in institutional change processes related to sustainability in education and in educational leadership and management. The observations presented in this text are shaped by my experiences and should be understood as reflections from a particular personal and institutional position rather than as a comprehensive evaluation of ESD at this university.

Chalmers University of Technology, which is Sweden's second-largest technical university, has long been recognised as a pioneer in engineering education for sustainable development. Environmental courses began to emerge already in the 1980s, initially as add-ons in existing engineering programmes. Early developments were largely driven by committed faculty members with expertise

and interest in environmental issues. During the 2000s, these efforts evolved into a more systematic approach and quality assurance through a university-wide transformation initiative, 'the ESD project' (2006–2009). Supported by strong commitment from the university leadership, the project promoted the integration of sustainability into all engineering programmes (Holmberg et al. 2012). A key principle was that the content should be tailored to the context, challenges, and professional practices of each programme, at the same time as sustainability was to be addressed explicitly and visibly within the curriculum.

However, despite these achievements, it can be argued that the university has not yet undergone a broader transformation towards what has been described in literature as sustainable education, where sustainability fundamentally shapes educational purposes and pedagogical approaches (Kolmos, Hadgraft, and Holgaard 2016; Sterling 2004).

Against this background, I will here reflect on the following four current trends that I have observed at Chalmers, their potential drivers within the university and the broader Swedish and European and international context in relation to insights from selected papers in this special issue on developments at other universities:

- Trend 1: There has been stagnation in the further development when it comes to the environmental dimension of sustainable development;
- Trend 2: Aspects of the social dimension of sustainable development have had a positive development;
- Trend 3: Students do not perceive sustainable development as a future career path; rather, they view it as a concern to be addressed in their spare time;
- Trend 4: Industry-formulated competence needs lack an explicit articulation of sustainability.

Trend 1: stagnation in the further development of the environmental dimension

Some of my colleagues at Chalmers University of Technology, who are teachers in the environmental domain of sustainability, perceive stagnation in the further development of sustainability in the educational programmes. Even though all programmes seem to fulfil the university's requirement (i.e. 7.5 ECTS in environment and sustainability, which is ambitious compared to national requirements), there are large variations among the programmes in their level of success and ambition. A few programmes still include sustainability just as an add-on, which, here, means that sustainability is included in just a separate course and not progressively integrated in several courses. Furthermore, there is no university-wide work going on for a transformation towards sustainable education. A concern is that Chalmers' position as a front-runner may be challenged as other universities are potentially catching up, due to a decline in momentum that happened at some time after 'the ESD project' concluded in 2009.

There are different possible reasons for this stagnation at Chalmers as well as variations among the educational programmes. Programme directors in some engineering disciplines where sustainability integration has progressed relatively far may perceive that the goals of ESD have already been achieved and that no further efforts are needed. From this perspective, proposals have even been put forward to remove the university-wide requirement concerning environment and sustainability in education. Similarly, within student recruitment, sustainability is viewed by some as being so thoroughly embedded in the educational programmes that references to sustainability have been removed from the titles of Master's programmes. A possible explanation for these perceptions is that the next stage of development is not always easy to envision. Moving beyond the integration of sustainability towards a more transformative approach would require a paradigm shift in the conception and design of engineering education. In the absence of well-established examples, it can be difficult to articulate what such a shift would entail in practice, which may contribute to the perception that the work is already complete.

In other engineering disciplines, where sustainability integration has not advanced to the same extent, some programme directors may nevertheless perceive the current level of integration (i.e. 7.5 ECTS in a separate course) as sufficient and see no need for further development. Possible reasons for this include rejection, denial or lack of responsibility for sustainability, prioritisation of technical content over sustainability-related content, or lack of competency, support, time or resources, which is in line with the findings by Bolstad, Verhulst, and Henriksen (2025).

The university's vision has been changed from ' … for a sustainable future' to ' … for a better world' (Chalmers University of Technology 2025). While the university strategy continues to emphasise the need for sustainable change and explicitly acknowledges the role of technology in creating current sustainability challenges, sustainability has become less prominent as an overarching institutional message. This can be seen to be in line with a general trend in Swedish society where sustainability is no longer among the top priorities for politicians. Both politicians and university management have, in recent years, prioritised other topics, such as national security and defence, AI, and the competitiveness of Swedish industry. This in turn reflects broader geopolitical developments, such as the war in Ukraine and in Europe's surrounding region.

This trend may therefore be understood not only as a consequence of local decisions and changing priorities at Chalmers, but also as part of a broader shift in the institutional conditions. This interpretation is supported by Menon et al. (2025), who highlight that, despite the widespread recognition of sustainable development as a priority in engineering education, its implementation remains uneven. Their comparison of universities in Denmark and the United States suggests that successful integration depends heavily on national and institutional support. Where such support is strong, as it used to be in Sweden and at Chalmers, sustainability integration is facilitated; where it is weaker it will rely on individual teachers' commitment.

Trend 2: positive development in the social dimension

In contrast to the previous trend, integration of aspects of the social dimension of sustainability in the educational programmes has expanded at Chalmers in recent years. For several decades, all engineering programmes have been required to include 7.5 ECTS in Human, Technology and Society (MTS), a university-wide requirement that goes beyond the expectations of the national degree ordinance, and that is additional to the university requirement of 7.5 ECTS in environment and sustainability described in Trend 1. Although MTS has not traditionally been associated with sustainability, its focus on the role of technology in society, including both its opportunities and its challenges, encompasses issues that are highly relevant to sustainable development.

Building on this foundation, in more recent years, ethics has been integrated more explicitly in the educational programmes, also in other courses, since approximately ten years back (Lundqvist 2016), and EDI, i.e. equity, diversity, and inclusion, since approximately five years back. The recent development has been driven by national evaluations of higher education in combination with goals formulated by the university that are more ambitious than the national requirements. It is carried out in the usual Chalmers way, by integration into a relevant selection of courses within the programmes (Holmberg et al. 2012; Lundqvist 2016). This is done by teachers in engineering fields who have received some competence development and support from subject specialists in ethics and EDI, to ensure relevance for professional practice, engineering design, and technology development processes. While this is driven by university-wide goals and expectations, the practical implementation tends to depend on those teachers who are most willing to engage with the initiative, due to an interest in these issues or because they hold responsibilities for programme development and quality assurance.

The prioritisation of the social dimension is reasonable, given that it has historically been the weakest component of sustainability in education at Chalmers. It is also motivated by broader societal developments that have made social sustainability increasingly central. In Sweden, challenges

such as segregation and declining trust between different groups, as well as between the public, decision-makers, and scientists, have become more pronounced. Globally, democratic backsliding, geopolitical instability, and increasing local and global inequalities are key concerns. In addition, the long-term trend of reducing extreme poverty has recently stalled and, in some regions, partly reversed (Development Initiatives 2023).

The challenge of an overly narrow focus on environmental concerns is highlighted by Menon et al. (2025). Referring to findings from previous studies, they note that engineering educators and programme leaders often have a relatively limited understanding of sustainable development, with environmental issues receiving most attention, while social and cultural dimensions, such as equity, justice, working conditions, inclusion, and the societal implications of technological development, are less frequently addressed.

Lucena et al. (2026) similarly point to the limited emphasis on broader socio-technical perspectives in engineering education. They emphasise the importance of social and community-related knowledge and perspectives, which are often less visible in engineering education.

Trend 3: students do not perceive sustainable development as a future career path

At Chalmers, fewer students seem to choose programmes with an explicit sustainability profile, while traditional programmes such as Mechanical Engineering are growing in popularity. This may reflect a broader shift among Swedish youth away from climate-related concerns towards economic security and other more immediate issues (Rasmussen and Hennerda 2025). According to representatives of Ungdomsbarometern AB (personal communication 2026), sustainability is increasingly viewed as a private interest rather than a career path. A potential reason behind this may be that they are uncertain about job opportunities with such an education, which is a strong driving force in their choice of education.

This is in line with Appelhans et al. (2025), who demonstrate that students' educational choices, in a study conducted at a university in the USA, are not driven solely by personal interests such as sustainability, but also by personal goals, perceived ability to succeed, and expectations of future career opportunities. This helps explain why, although many students initially express a desire to contribute to societal good, they do not choose a sustainability pathway.

Complementing this, Nießner and Rosén (2025) show, based on focus group workshops with students of different nationalities and from a range of higher education programmes – including engineering and other professionally oriented fields – that students express a strong interest in sustainability but often perceive it as a peripheral add-on rather than an integral part of their studies. This, in turn, limits its perceived relevance for their future professional paths, as isolated additions are seen as disconnected from their disciplinary learning.

Trend 4: industry-formulated competence needs lack an explicit articulation of sustainability

According to my observations, Chalmers' strategic partner companies (i.e. primarily larger companies in the region) continuously demand competencies related to sustainability; however, this is not always articulated explicitly in terms of 'sustainability'. Instead, it is often framed through domain-specific competencies, such as those associated with circular economy. In general, this demand is expressed in the context of industrial competitiveness rather than as a need for a transition towards sustainability. A similar pattern can be observed in how the Swedish state formulates the need for lifelong learning for the green transition, where the emphasis is placed on strengthening professionals' position in the labour market. This also suggests that sustainability is not a niche concern associated with particular engineering disciplines, as the competence needs articulated by industry are broad in scope and relevant across the engineering profession.

These observations are in line with the results reported by Karvinen et al. (2026), who identified that Finnish employers emphasise technical skills and implementation capabilities, while sustainability-specific knowledge is seldom explicitly highlighted as a key future competency. Sustainability is expected to be applied implicitly within disciplinary work rather than treated as a separate domain. Furthermore, employers expect graduates to independently apply sustainability in their work and demonstrate initiative and value-driven action. Sustainability is framed as agency and mindset rather than a distinct competence category.

This is not necessarily a new development. Industrial competitiveness and engineers' disciplinary knowledge have, understandably, always been prioritised. A potential shift, however, is that sustainability is being articulated less explicitly in societal discourse, by industry as well as by policymakers and universities, as highlighted under Trend 1 above.

Concluding remarks and way forward

While a stagnation can be identified with regards to the environmental dimension, and notable progress with regards to the social dimension, the environmental dimension still appears to be more mature than the social dimension. Although the latter has expanded considerably, evaluations of recent initiatives suggest that further development is needed, both in terms of the depth of learning outcomes and the range of social sustainability issues addressed.

One possible explanation for the opposite trends for the environmental and the social dimensions is that development has primarily occurred where the perceived sense of urgency has been greatest, in this case largely driven by national evaluations of engineering education. At the same time, there are practical limits to how much change teachers and programme directors can manage simultaneously. This observation resonates with Cuevas-Garcia's (2025) notion of patchwork transformations, where multiple change initiatives coexist and compete for attention and resources within universities. An additional challenge that may have caused stagnation is the lack of a clear vision and well-developed examples of what advanced or transformative sustainability education could look like in practice.

A further observation concerns young people's reluctance to choose programmes with an explicit sustainability profile, combined with a decreasing tendency among industry and society to articulate sustainability needs explicitly. Instead, other priorities – such as industrial competitiveness and national security – have gained prominence in societal discourse. This shift has likely influenced young peoples' educational choices. Despite this, there remains an implicit demand for sustainability-related competencies, often linked to industrial competitiveness, that is not always well recognised by young people, industry HR functions, or even all teachers.

It should also be noted that the competencies most explicitly requested by industry and policymakers are often presented as relating to environmental sustainability challenges (such as circular economy and green transition), although social aspects are frequently embedded within these challenges. This may overshadow the importance of the social dimension. Although the need for social sustainability competencies is evident, they are not always clearly associated with the engineering profession.

Taken together, these observations regarding the articulation of sustainability needs create a risk that sustainability competencies are undervalued and that educational programmes do not fully respond to existing needs. They also raise the concern that industry competitiveness alone may not be a sufficiently strong driver for achieving a broader transition towards sustainable development.

These observations also highlight the limitations of relying solely on currently articulated competence needs. As Dahlin (2026) argues, universities are expected not only to respond to existing labour-market demands but also to anticipate future societal needs and support students in developing competences that enable them to engage critically with alternative futures and long-term societal transformations.

A noteworthy observation is that several of the competences highlighted in UNESCO's framework for Education for Sustainable Development (UNESCO 2017), including systems thinking, critical thinking, collaboration, and integrated problem-solving, can already be identified in the national degree objectives for the Swedish Master of Science in Engineering degree (Swedish Government 1993). At the same time, some of the more transformative competences emphasised by UNESCO, particularly those related to engaging with alternative futures and reflecting on personal values and responsibilities, remain less visible. This suggests a need to further explore what it means to educate engineers not only to meet present needs but also to contribute to future sustainability transitions.

A possible way forward would be to initiate and lead a discussion involving both internal and external stakeholders on the professional role and responsibilities of engineers. The aim would be to foster a professional identity in which contributing to sustainable development is seen as an integral part of engineering practice. The national degree requirements provide a valuable foundation for such discussions, but there remains a need to explore their implications for engineering education and the role of engineers in the transition towards a more sustainable society. Notably, a similar perspective is reflected in the Code of Honour of the Swedish Association of Graduate Engineers, which states that 'Engineers should, in their professional practice, feel a personal responsibility to ensure that technology is used in ways that benefit people, the environment, and society' (Sveriges ingenjörer 2026).

In addition, there is a need to move beyond Chalmers' current requirement of 7.5 ECTS in environment and sustainability in all engineering programmes. While this requirement has been important in establishing a baseline, it risks reinforcing an add-on approach when attention is directed primarily towards the allocation of credits. Instead, greater emphasis should be placed on qualitative criteria that support more transformative educational development. This would acknowledge the statement by the Swedish Higher Education Authority (UKÄ) in their evaluation of Swedish universities from 2017 that sustainability is not a state to reach, but a process that has to be engaged with continuously (UKÄ 2017).

The current terminology at Chalmers may also be problematic, as the label environment and sustainability can imply that the environmental dimension holds a special status relative to other dimensions of sustainability. A stronger focus on sustainability as an integrated concept – encompassing environmental, social, and economic dimensions – could help promote a broader understanding among both industry stakeholders and university staff. Indeed, discussions suggesting that attention should shift from environmental sustainability to social sustainability may themselves reflect a tendency to treat these dimensions as separate rather than deeply interconnected. What is needed is not a rebalancing between competing dimensions, but a more comprehensive engagement with the complex relationships between environmental, social, and economic challenges. It may also encourage engagement with the political dimensions of sustainability, including questions of power, values, and wicked problems that challenge conventional disciplinary perspectives.

Challenging dominant perspectives with views from the South

Universities in the global North have increasingly positioned ESD as a driver of transformation, through reorienting curricula, research agendas, and campus cultures towards addressing sustainability concerns (UNESCO 2017). Yet the transformation that ESD aspires to remains elusive, which has necessitated more critical and integrative approaches for incorporating sustainability in theory and practice, especially in engineering education (see Bolstad et al. 2025; Cuevas-Garcia 2025, in this Special Issue). For more critical interpretations of what transformation ought to result in, some scholars have turned towards the concept of decolonisation. In the context of higher education, this refers not to territorial decolonisation, but decoloniality - the idea that the lingering effects and legacies of colonialism on individuals, societies, and the institutional cultures and structure of universities must be acknowledged, interrogated, and redressed (Ndlovu-Gatsheni 2018). However,

decolonisation too is a contested concept. There is a lack of consensus about its meaning because it can be interpreted differently (Jansen 2017; Zwane 2019). Consequently, there are varied ways of thinking about its implementation in teaching and learning (Davids 2024; Le Grange and Du Preez 2023; Luckett 2016). As this section of the editorial will show, transformation and decolonisation might be different in their ambitions, but they share a similarity in their concern with the ongoing struggle for profound change. This is a struggle for change not only in terms of who gets to access, participate in and succeed in higher education (transformation) but also in the worldviews that underpin the onto-epistemological foundations of universities (decolonisation). Despite the apparent limitations of both concepts, transformation and decolonisation have analytical purchase because they together prompt critical reflections about what needs to change with regards to sustainability in engineering education. We therefore take the opportunity to engage scholarship on transformation and decolonisation of higher education, focusing mostly on literature from South Africa. We do this for three reasons:

(1) There is limited engagement in this special issue on scholarship from the Global South and even less engagement with literature produced by African scholars. This is despite the fact that there is a small but growing body of work that is pioneering ideas on decolonising engineering education with implications for sustainability (see Assibey et al. 2025; Occhio et al. 2023; Nuamah and Peng 2024).
(2) There is a growth in compelling literature by scholars who argue that transformative sustainability learning requires challenging dominant norms, values, practices and worldviews (Sterling 2024; West et al. 2024; Williams et al. 2018). Considering what might change if different perspectives and views from the South are taken up more in operationalising and translating sustainability in engineering education is one way of challenging dominant perspectives that are largely informed by Northern and Western worldviews and scholarship from the global North.
(3) One of the guest editors, Mikateko Mathebula, is a researcher from South Africa whose interests sit at the intersection of higher education, human development and sustainability, which she has explored through the lens of the capability approach in her work on engineering education. In her recent publications, she has engaged more with ideas around decolonisation and worked with ubuntu philosophy as an interpretive framework for understanding the value of university education for low-income youth. We leverage the knowledge and expertise that she brings to this special issue in this section.

Analytical purchase of 'transformation'

In South Africa, the basic pattern of engineering education that was inherited from British colonialism at the turn of the nineteenth century has remained largely untransformed (Kloot and Rouvrais 2017). This is a type of engineering education that contributed to a lack of recognition of, or action against, the unjust system of apartheid, instead enhancing the sense of a 'social cocoon' which shrank engineers' agency in critically engaging with the social and/or political imperatives of universities and society (Shaw and Kloot 2025). As one participant in Shaw and Kloot's (2025) study of engineers who practised during apartheid reflected: 'you don't read widely ... your focus is on technical stuff, not on broader issues of life'.

Following the democratic transition of 1994, transformation became the organising concept for dismantling the legacies of apartheid in educational institutions through various changes in policy and practice (Luescher et al. 2023). Three decades on, however, the promise of transformation is contested, and new proposals for reimagining how it can be achieved continue emerging (Bergsteedt and du Plessis 2026). Some scholars have argued that part of the problem lies in how transformation is narrowly operationalised, such that its intellectual, political and moral content becomes institutionalised (Lange 2014; Ramrathan 2016). By 'institutionalised', Lange (2014) means that the policies

and general orientation of universities in South Africa lack nuance because the term: 'has been reduced to the numbers, percentages and ratios of black and white people and, to a lesser extent, men and women involved in or accepted into institutions, professions, positions, education, etc'. (Lange 2014, 4). However, as Mkhize (2023) demonstrates through research on the lived experiences of African women in STEM in South African universities, increasing access and diversifying student populations alone does not in itself constitute transformation. Especially when other variables like class, sexual orientation, and disability do not make it into the statistical cut (Lange 2014). When this happens, what is considered good signs of institutional change may instead be 'reform of the system masquerading as transformation' (Mkhize 2023, 639). Similarly, De Vos and Riedel (2023) draw on a South African curriculum study to argue that transformation efforts often remain tokenistic, i.e. partial, inconsistent, and unable to challenge existing epistemic norms. This paradox is not unique to universities in South Africa. It is prevalent in efforts to transform universities through ESD in the global North, where higher education is both a catalyst for change while being complicit in maintaining unsustainable practices (Sterling 2024, see also Nießner and Rosén 2025 and Peters and Rosén 2025 in this special issue). As Zhou (2025) explains based on a review of how universities in the UK are interpreting sustainability: branding exercises, sustainability offices, 'green washing' campuses and routine, and tokenistic curriculum additions, are examples of what often takes place instead of substantive transformation.

A lesson that can be learnt from South African scholarship on transforming higher education is the distinction between surface-level reform and genuine change in structural terms, similar to what Högfeldt (2026) in this special issue describes in terms of 'expansive change'. In their state-of-the-art report, Luescher et al. (2023) highlight that meaningful transformation requires change not only of curricula but of the governance structures and practices that control institutional resources and priorities. Universities in the global North can be similarly constrained from genuine transformation when sustainability and ESD are siloed in sustainability offices or elective courses rather than embedded in the decision-making architecture of faculties and departments (see Menon et al. 2025 in this special issue). Moreover, engineering faculties in global North contexts are at risk of limiting transformation to tokenistic approaches if they simply add sustainability topics without interrogating how knowledge and understanding of the concept is shaped by prevailing injustices (Sultana 2024).

At this point, it is important to acknowledge the papers in this special issue that do begin to raise fundamental questions about the normative and political dimensions of engineering practice and, by so doing, point out problems that are inherent in engineering education. Several papers tentatively and/or implicitly pose questions about what transformation of engineering education is for, and for whom this transformation is beneficial. For example, Cuevas-Garcia's (2025) 'patchwork transformation' framing offers a fine-grained account of universities as heterogeneous entities that are pursuing multiple and sometimes incompatible goals. The paper shows that within the same institution, it is possible for some initiatives to promote market-driven solutions to climate degradation, e.g. the production of profit-oriented 'sustainable' products, while courses offered by the same university problematise this way of thinking about sustainability to discourage naïve assumptions about the relationship between capitalism and environmental damage. In a different vein, Lucena et al.'s (2026) community-engaged model that repositions the university in relation to society raises important questions about relationality, which is a central component of many indigenous perspectives that are challenging conventional and dominant ways of understanding the relationship between human beings, non-human beings and the natural environment (Peters and Rosén 2025). It is for this reason that Nießner and Rosén's (2025) call to give students real power rather than performative voice matters. Ultimately, it is engineering knowledge that will feed into the design of products, processes, artefacts and technologies that will either advance or deter ecological repair.

When these issues are considered together, the question becomes not how we can orient engineering education towards sustainable development. Rather, the question becomes whether engineering education seeks to produce:

(a) engineers who are better at managing sustainability problems within existing systems,

or

(b) engineers who are enabled to challenge and transform the existing systems; be it through integrative, transformative, or de-growth and decolonial approaches.

As mentioned earlier under 'Emerging tension and gaps', integrative and transformative approaches to sustainability in engineering education are addressed within this special issue, but none of the papers engage in de-growth or decolonial approaches. In response to this, the next section draws mostly from literature on decolonising higher education in South Africa, to then theorise what decolonisation might entail in the context of engineering education. A discussion on de-growth approaches is beyond the scope of this editorial; however, we acknowledge this absence and see it as an avenue that warrants more attention in future issues of EJEE.

Necessity of the decolonial turn

The role of students as epistemic and political agents deserves particular attention in discussions on transforming and decolonising higher education. In South Africa, the 'Rhodes Must Fall' and 'Fees Must Fall' movements demonstrated that students are not merely beneficiaries of transformation but also among its drivers (Mathebula and Calitz 2018). Flowing from South Africa, related protests across Africa, Europe, and the US emerged and resonated differently across these contexts, but these protests were similar in expressing 'a need for a radical change to rupture and overcome structures of oppression, especially those shaped by colonialism' (Daniel and Platzky Miller 2025). Student activism and institutional critique have also functioned as essential drivers of reflexivity and democratic learning about various dimensions of sustainability, especially the social dimension, which, among other things, addresses questions of social cohesion (Martinez-Vargas et al. 2023; Mathebula et al. 2024). Moreover, student movements have gone a long way in challenging managerial governance cultures that prioritise procedural consensus over repairing structural injustices that perpetuate unsustainable practices (Masungo 2024; Muraina, Toshe-Mlambo, and Cingo 2024). Muraina, Toshe-Mlambo, and Cingo (2024) show that students consistently push beyond managerial definitions of transformation towards a more radical demand for epistemic and structural change - transformation that aligns with the decolonial imperative. Muraina, Toshe-Mlambo, and Cingo (2024) frame this as the central question of the decolonisation debate: whether transformation or institutional change work within or against knowledge structures that have been inherited from colonialism. In reflecting on this question, all engineers and engineering students should be given the opportunity to ask questions like:

- Whose futures are my sustainability competences designed to serve?
- From where do I draw knowledge to understand what sustainability means in theory and practice? and
- What kinds of relationships between humans, technologies, and ecosystems am I implicitly reproducing, creating or changing?

It is through such questions that students can begin to understand the ways in which technologies, including AI, can maintain systemic injustices ranging from racism (Hofmann et al. 2024) to sexism

(Noble 2013). This point is made well by Noble et al. (2024), who use intersectional feminist theory to explain how search engines inherently carry discriminatory biases. As explained by Pastierová (2022), search engine algorithms are designed to rank and prioritise results according to factors like relevance of the information for user intent, search traffic, and popularity of a specific search result. These ranking algorithms can produce search engine bias through processes of weighting specific factors or by including search results that are paid for by advertisers, for instance (Pastierová 2022). Noble (2018) and other scholars have pointed out that this bias is present in search engines, not only because of aggregated data from user behaviour, but also because it is embedded directly via coding, thus raising critical questions about software engineering.

A popular example of how this bias plays out can be found in Google's history of producing search results that are racist, sexist, and reflect other offensive values (Cadwalladr 2016; Noble 2013; Noble et al. 2024). Cadwalladr (2016) illustrates this by referring to the result she received from typing the question 'are Jews … '. Among the autocomplete suggestions appeared the words: 'are Jews evil?' which led to links with problematic content, including neo-nazi rhetoric. These autocomplete suggestions have since been changed, but the example here shows that technologies and search engine algorithms are not neutral or unbiased but instead often reflect dangerous biases with implications for social justice (Pastierová 2022). In fact, Noble et al. (2024) predict that racist technologies will be among the most pressing human, civil, environmental, and sovereign rights issues of the twenty-first century. If engineers are to be on the right side of history, engineering education must take these problems into account and make the inherent biases in different types of technology apparent to all engineering students. Decolonising the discipline could be a possibility for doing this.

Another possibility lies in networks like Engineering, Social Justice, and Peace (ESJP) - a group of academics, practitioners, and students from a range of disciplines. Although they do not refer to what they do as 'decolonial', there is clear alignment with their work because they seek to promote engineering practices that enhance gender, racial, class, and cultural equity based on values of democracy, non-oppressiveness, and non-violence.

For those who need convincing about the need to work with the idea of decolonisation, there is compelling literature that explains carefully why it is not enough to reform curricula or add diverse content in engineering study programmes. These texts make it easy to understand why it is necessary to fundamentally rethink the discipline's purpose, structure, and relationship to land, people, and power (Masta et al. 2026) but also to coloniality and capitalism (Sultana 2024). This literature suggests that the effects of coloniality remain insufficiently addressed in current scholarship on sustainability in engineering education. As Masta et al. (2026) explain, decolonial approaches would begin by confronting the fact that engineering has served colonial ambitions – through nation-building, westward expansion, and the export of extractive and exploitative development models and technologies that can perpetuate rather than mitigate structural injustices.

Scholarship in the area of decolonising engineering education seems nascent, but there are a few examples. Based on research in South Africa, Winberg and Winberg (2017) discuss approaches to decolonise engineering curricula using a social justice framework, while Adendorff and Blackie (2020) draw on Legitimation Code Theory. Moving from theory to practice, Mathaba (2023) illustrates through research with chemical engineering students at the University of Johannesburg, how indigenous knowledge practices from traditional food processing to material separation techniques could enrich engineering curricula. Agrawal and Heydenrych's (2024) research with undergraduate chemical engineering students at another South African university shows the potential for transformative learning when decolonisation initiatives are implemented to shift the epistemic ground on which engineering education is rooted.

Collectively, these papers offer a limited but important view from the South; one that suggests a specific agenda of making coloniality in engineering knowledge an explicit object of critical inquiry (Masta et al. 2026). This is an agenda that treats indigenous, community-based, and Global South epistemologies as epistemic resources rather than cultural content; that cultivates student voice and collective agency in curriculum design - as demonstrated by engineering students who are actively

shaping decolonisation debates (Mathaba 2023). It is an agenda that speaks of transformation that is difficult to specify in instrumental competence frameworks, which the literature here suggests that engineering education would benefit from. For the European context, an interesting opportunity might lie in the EU GreenComp competence framework (Bianchi, Pisiotis, and Cabrera Giraldez 2022). It moves well beyond purely technical definitions of sustainability and instrumental skills, explicitly recognising that sustainability is value-laden, contested, and politically charged, and might offer an entry point for European engineering education to engage with these perspectives.

From an ESD perspective, these insights are valuable because wicked problems are inherently complex and require straddling competing values and disagreements about the extent to which 'sustainability' will lead us to desirable futures (Masta et al. 2026). As the next section shows, the decolonial agenda is linked to an understanding of sustainability competence not as a capacity held individually, but as relationally constituted and as a collective pursuit (Martinez-Vargas et al. 2023). Importantly, an integrative review by Shajahan Shahjahan and Seinn (2025) indicates that the discourse on decolonisation in engineering education is predominantly centered in Africa and North America. The need for perspectives from other Global South regions, including the Caribbean, East Asia, South Asia, Latin America, and the Middle East, is clear (Shahjahan and Seinn 2025).

Value of indigenous worldviews

Sustainability challenges – e.g. climate change, biodiversity loss, resource depletion, energy inequality – are not epistemically neutral problems with technical solutions; rather, they are embedded in specific colonial and extractive histories (Sultana 2024). Histories that engineering as a field has played a major role in. These histories have contributed to indigenous people's knowledge being pushed to the margins (Ndlovu-Gatsheni 2018) and to the eradication of indigenous cultural practices and spiritual beliefs that were conducive to living more harmoniously with nature than modern societies do (Egri 1997). For example, the San, who are considered the first inhabitants of Southern Africa, persisted with following a hunter-gatherer lifestyle as opposed to adapting to modernised approaches to farming and development (Lee 1979). It is now known that most modern forms of large-scale industrialised farming and agriculture are unsustainable because they contribute to land degradation and climate change (IPCC 2019). Many indigenous worldviews, philosophies and traditional beliefs across the world, including Africa, teach the importance of living in harmony with nature and with fellow human beings, which is the 'logical essence of sustainability' (Mebratu 1998, 518). It is therefore important to acknowledge that historical and contemporary examples of more sustainable relationships between people and planet exist across the world, and that examples of what we might now consider sustainable practices are not new to Africa. However, African worldviews are susceptible to neglect or being overlooked as valid sources of knowledge, so they seldom feature as a basis for thinking about sustainability in general, let alone in the context of engineering education. Instead, European perspectives form the basis for defining valued ways of being, doing and learning about sustainability in Africa (Wa Thiong'o 2004). This not only leads to indigenous worldviews and local knowledge being undermined, but it perpetuates the dominance of Eurocentric thinking in debates about sustainability (Grosfoguel 2007).

Although perspectives that centre Europe as an epistemic site have been used to uncritically construct sustainability narratives for the rest of the world, there is compelling literature that demonstrates the value of African worldviews and philosophies for nuanced understandings of sustainability in general (Assibey, Chisin, and Chmela-Jones 2025), the SDGs (Van Norren and Seehawer 2025), and sustainability in engineering education (Occhio et al. 2023). For example, the philosophy of ubuntu – often summarised through the aphorism umuntu ngumuntu ngabantu ('a person is a person through other persons') – offers a particularly generative resource for reimagining

the relational and ethical foundations of ESD in engineering (Occhio et al. 2023). Kyei-Nuamah and Peng (2024) demonstrate how ubuntu's core concepts – humanness with humaneness, afro-eco-communitarianism, and relational stewardship – can be mobilised to develop environmental education pedagogy and policy that foregrounds the interdependence of humans and ecosystems rather than centre individual agency and managing planetary boundaries. In engineering education, an ubuntu-inspired orientation would shift the primary question from 'what sustainability competences can this individual demonstrate?' towards 'what kinds of relational, collective, and long-term responsibility does this engineering practice sustain or undermine?' – a reframing that is not incompatible with GreenComp's aspirations, but which enriches them. As done in this special issue by Karvinen et al. (2026) and Dahlin (2026), the competencies that engineers need are often described in terms matching industry, employer, and sustainability managers' expectations. However, as Fataar (2025) argues, any competence frameworks that are developed without interrogating the epistemological foundations of engineering disciplines tend to narrow their focus towards favouring curriculum reform for technical proficiency and market readiness while neglecting rigorous critique, ethical reflection, and epistemic plurality.

The importance of epistemic plurality is acknowledged but underappreciated in this special issue. For example, papers by Bolstad, Verhulst, and Henriksen (2025), Gutierrez-Bucheli et al. (2025), and Högfeldt (2026) are important because they provide normative and practical frameworks for how sustainability can be integrated into the curricula of various engineering programmes. Across all three papers, the focus is predominantly on formal institutionalised processes of learning, where recommendations tend towards formal models or frameworks for sustainability integration. Although valuable, these findings contrast with the nuanced account by Laakso and Hallberg Adu's (2024) research with faculty experiences across four African countries, which underscores that meaningful change tends to happen in the 'unofficial curriculum' – in the relational pedagogical encounters between teachers and students – rather than through formal integration or framework adoption. Notwithstanding the contextual differences, there are lessons that can be learnt from other parts of the world where different epistemologies highlight relationality in learning. However, as Motala (2025) argues, epistemic inclusion is always materially conditioned: whose knowledge counts in a curriculum reflects whose resources, languages, and institutional positions are recognised.

If indigenous worldviews are recognised and valued, they can help to illuminate problems that engineering education must address if sustainability is to be genuinely transformative rather than a continuation of the developmental hierarchies it claims to transcend (Van Norren, 2024, 2022). However, it will not work to simply incorporate diverse worldviews and sustainability perspectives as case studies or supplementary readings while leaving the core epistemological assumptions of engineering science untouched (Masta et al. 2026). This will merely reproduce the tokenism that African scholars have identified as the hallmark of reform rather than genuine transformation (Masta et al. 2026). Therefore, as Govender and Naidoo (2023) argue, it is necessary to shift towards genuinely pluriversal epistemologies that validate multiple ways of knowing as equally legitimate starting points for engaging with sustainability. Although beyond the scope and content of this special issue, we see questions about the co-existence and challenges of merging diverse epistemologies in engineering education as an area that warrants further exploration in future issues of EJEE.

Concluding thoughts

The South African higher education literature that was discussed in this part of the editorial provides a rich set of perspectives, not only in thinking about what is taught in engineering programmes, but who counts as a knower, whose futures are centred, and what kind of world engineering education is ultimately in service of. As universities in Europe scale up ESD commitments in response to policy pressures from the European Green Deal, the Bologna Process, and UNESCO's ESD roadmap, views

from the South problematise how we understand the notion of sustainability to begin with. These views can positively shape the evolution of the way we think about sustainability in general, and how we think of it in the context of engineering education. Engaging with these perspectives is therefore not an act of exotic enrichment but necessary to illuminate the blind spots that come from parochialism.

Concluding synthesis and look ahead

The 17 contributions to this special issue suggest that sustainability in engineering education might be entering a new phase of development. While Gardelle, based on a review of papers from the preceding 15-year period, characterised the field by a positivist 'what works' orientation focused on solutions, we see a larger share of critical perspectives and conceptualisations. The question is no longer primarily whether sustainability should be incorporated into engineering education, nor simply how it should be integrated into syllabi and curricula, but increasingly what kinds of engineers, engineering knowledge, educational institutions, and societal relationships are needed to navigate the prevailing state of polycrisis and profound socio-ecological transformations. While the field is moving beyond the add-on phase that characterised its early development, the special issue papers collectively show that transformative ambitions remain only partially realised. Progress is evident, but it remains uneven and strongly dependent on individual initiatives, disciplinary traditions, institutional priorities and national contexts.

Rather than converging on a common model, the special issue contributions indicate a field characterised by multiple conceptual tensions, for example: technical solutionism versus socio-technical framings of engineering problems; industry alignment versus proactive societal leadership; global sustainability frameworks versus locally situated meaning-making; and cognitive conceptions of learning versus more relational, affective, and existential perspectives. These should, in many cases, probably not be understood as inconsistencies to be eliminated, but as expressions of a field that is becoming increasingly reflexive about its own assumptions. Rather than resolving these tensions, the special issue contributions demonstrate that they can be vivid zones of ongoing inquiry. These tensions further highlight the trouble of accepting multiple co-existing, partly conflicting agendas, such as, on the one hand, industry's short-sighted commercial realities and graduates' need for income, and, on the other hand, the calls for systemic change and transformation.

Two perspectives developed in this editorial illuminate why some of these tensions persist. The reflection on Chalmers shows how an early, genuinely pioneering integration effort can stagnate once sustainability becomes a matter of credit allocation and when sustainability recedes from institutional visions and public discourse in favour of AI, industrial competitiveness and national security. The South African scholarly views on transformation and decolonisation shows that curricular and institutional reform might be claimed without disturbing the underlying assumptions about whose knowledge counts, what engineering is for, and whose futures it is designed to serve. Viewed together, these two sections suggest that sustainability efforts that are limited to technical and curricular adjustment – without engaging the purposes, governance structures, power relations, and worldviews that shape engineering education, engineering, and technology – are likely to stall regardless of how well-intentioned or well-resourced they are. While the Chalmers case demonstrates both the opportunities and the limitations of integrating sustainability within a predominantly reductionist paradigm that tends to separate environmental, social, and economic concerns, the South African scholarship challenges that paradigm itself and points towards more transformative approaches to sustainability in engineering education.

Regarding future work, multiple directions are proposed in the discussions and conclusions sections in the special issue papers. Based on the synthesis and identified tensions and gaps in this editorial, we can provide some additional recommendations. Despite the observed plurality among the special issue contributions, future scholarship could benefit from expanding both its ontological,

epistemic, and geographical diversity even further. This could, for example, involve stronger international collaborations beyond Europe and the Global North. It could also involve engagement with community-based and indigenous epistemologies, alongside decolonial, degrowth and feminist perspectives, which all could carry strong transformative potential while remaining markedly underrepresented in this special issue and in engineering education research in general. As sustainability challenges themselves become increasingly complex and contested, engineering education similarly requires a plurality of conceptual lenses capable of illuminating different dimensions of change rather than converging prematurely on a single framework.

This could also be connected to discussions on a post-2030 agenda. As 2030 approaches, the limits of the SDGs are becoming increasingly apparent – not only in terms of measurable progress, but in terms of the underlying conceptual and political architecture that shapes what is measured, for whom, and by whose standards. Scholars across the world have raised sustained and incisive critiques of the 2030 Agenda that deserve serious attention from engineering educators and ESD researchers. For example, greater attention could be devoted to governance, leadership, and organisational conditions, recognising that transformation depends as much on institutional structures, incentives, and cultures as on curriculum design and pedagogy. More longitudinal work could also be devoted to tracing how sustainability competencies, professional identity, workplace and societal agency develop over time. Assessment is yet another area that has been given practically no attention in this special issue, which requires further research and development; how transformative learning might be evaluated without collapsing into narrow proficiency indicators.

Whether this amounts to the beginning of a paradigm shift, as some of the more critical contributions to this issue gesture towards, or a further, deeper phase of integration, remains an open question. What this special issue does suggest is that engineering education is increasingly being asked, not only to equip graduates to solve sustainability problems within existing systems, but to prepare them to question inherited assumptions, navigate genuine uncertainty and competing values, and participate in shaping more just and sustainable futures. This is a matter of curricula, but arguably even more of institutional cultures, openness to critical inquiry, epistemic plurality, and democratic participation that goes beyond what curriculum reform alone can deliver. This special issue does not offer definitive answers to what such an education would look like, but it offers an invitation to continue that conversation, within this journal and beyond.

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