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What does it mean to be engaged? The engagement of student engineers with sustainability: a literature review

Aida Guerra, Dan Jiang and Xiangyun Du
Department of Sustainability and Planning, Aalborg University, Aalborg, Denmark and Institute of Advanced Studies on PBL, Aalborg University, Aalborg, Denmark

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Abstract

Purpose – Student engagement has become increasingly significant in sustainability education for engineers because it enables future engineers to develop competencies, knowledge and values relevant to acting for sustainability. Therefore, this paper aims to examine characteristics of student engineer engagement with sustainability and to discuss the meanings of this concept.

Design/methodology/approach – To build a more holistic picture of student engineer engagement with sustainability, this study followed a literature review approach to search, screen and appraise relevant journal articles on this topic. As a result of this research, 30 articles were identified as eligible.

Findings – Based on the theoretical framework for student engagement with sustainability, newly synthesized here, and the content analysis of the 30 papers included in this study, four patterns of engagement were identified: intrapersonal engagement, inter-relational engagement, engagement as connection and disconnection and situated engagement.

Practical implications – This review provides practical recommendations about how to support the engagement of student engineers with sustainability at the levels of the individual, staff, educational programmes and associated curricula. Future research directions are also discussed.

Originality/value – This study contributes a theoretical framework synthesizing student engagement theory with sustainability education. It also describes current characteristics of student engineers' engagement with sustainability.

Keywords Student engineer, Engagement, Engineering education, Sustainable development, Literature review

Paper type Literature review

1. Introduction

Student engagement plays an important role in educating for sustainable development (SD) by enabling students to develop the knowledge, competencies and values to act in favour of sustainability (Guerra, 2017; Sterling, 2004). Being engaged is primarily defined as the act or state of being involved, of being induced to participate or of being committed to doing or

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taking part in something. Literature defines engagement as a constructivist "meta-construct", where students are deep involved in purposeful activities with positive learning outcomes such as satisfaction, persistence, academic achievement and social engagement (Berger and Milem, 1999; Kuh, 1995; Kuh and Vesper, 1997; Pace, 1995; Fredricks *et al.*, 2004; Krause and Coates, 2008). In an educational context, learner engagement can be measured as the extent to which students act, collaboratively or otherwise, by becoming immersed in activities with the clear purpose of achieving personal, academic, societal or other meaningful goals. Student engagement is contextual, and time bound.

Engineers play a central role in achieving a sustainable, peaceful and fair future, while engineering education institutions have the duty to educate students for sustainability by equipping them with the knowledge and competencies to act accordingly (Muñoz-La Rivera *et al.*, 2020; National Academy of Sciences, 2021; Serafini *et al.*, 2022; UNESCO and ICEE, 2021). Although there is a worldwide recognition of the key role played by engineers and the importance of the learning environment required to provide education towards SD, there is still much to achieve such as increase engineering student engagement towards sustainability (Aleixo *et al.*, 2021; Klotz *et al.*, 2014).

Research carried out on the engagement of student engineers with SD has mainly focused on students' perceptions and awareness, the curriculum and integration strategies, with the majority using quantitative surveys as a research method (e.g. Aleixo *et al.*, 2021; Haase, 2014), or using a narrow perspective on engagement focusing only one dimension, e.g. contextual (Servant-Miklos *et al.*, 2023). However, these studies have paid little attention to what characterizes the engagement of student engineers for sustainability and how this can impact their learning by lacking a holistic and comprehensive approach to engagement. Engagement theory categorizes student engagement as multidimensional and complex, comprising different factors (e.g. behavioural, affective, cognitive and socio-cultural) which act as drivers for student engagement (Kahu, 2013; Trowler, 2010). Understanding in depth these factors can lead to a better understanding on what and how triggers student engagement contributes to more meaningful sustainability education in the engineering context. This requires more research to further explore and connect these perspectives in a holistic picture. This study aims to address that gap through the question:

Q1. What characterizes the engagement of student engineer for sustainability?

2. Theoretical framework for student engagement with sustainability

2.1 An operational definition of education for sustainable development

United Nations Educational, Scientific and Cultural Organization refers to education for sustainable development (ESD) as the education needed to "bring about the personal and societal transformation that is necessary to change course [. . .] of the collective activities of human beings have altered the earth's ecosystems," compromising their future (UNESCO, 2024). ESD aims to equip every human being with knowledge, skills, competencies and values needed to shape a sustainable future. That said, ESD is characterized as problem-oriented, contextual, inter- and transdisciplinary, collaborative, participatory, emancipatory and empowering, transformative and holistic (Annelin and Boström, 2022; Gutierrez-Bucheli *et al.*, 2022; Hermes and Rimanoczy, 2018; Sterling, 1996, 2004). ESD requires learning environments capable of deeply engaging students in their learning process, promoting a holistic and transformative education that fosters the development of sustainability values as well as the development of sustainability knowledge and competencies for action (Hermes and Rimanoczy, 2018; EU Science Hub, 2022; Redman and Wiek, 2021).

2.2 Defining student engagement in education

The literature surrounding student engagement provides different explanatory perspectives and dimensions (Appleton *et al.*, 2006; Kahu, 2013; Naji *et al.*, 2020; Wimpenny and Savin-Baden, 2013; Servant-Miklos *et al.*, 2023). Student engagement is a multifaceted construct that involves actions, practices and commitments students undertake within various spheres of their lives (e.g. educational, professional, private). Drawing from multiple perspectives, it incorporates cognitive, behavioural, psychological, social-cultural, dimensions of the individual. Table 1 provides multiple definitions and perspectives of student engagement according to literature in the topic, which authors used as point of departure to propose the theoretical framework presented in Section 2.3.

Recent studies in engineering education have related student engagement to different elements of how learning is organized and how it takes place, namely student feedback, approaches to learning, institutional organization, learning contexts, curriculum design and collaborative development, along with their potential as vehicles to improve student learning and outcomes (Naji *et al.*, 2020; Patterson *et al.*, 2011).

2.3 Theoretical framework for student engagement with, and for sustainability

Table 2 proposes a theoretical framework on student engagement with sustainability.

The theoretical framework will be used to define *à priori* coding themes for the content analysis of the literature selected.

3. Methodology

We conducted a search of studies about student engagement for sustainability in engineering education, applied predefined criteria to appraise those we found, and synthesized all studies shown to be relevant by this screening process. We followed the search-screen-appraise method advocated by Borrego *et al.* (2014) to conduct our literature review in the field of engineering education.

3.1 Step 1: Article search

3.1.1 Scoping study. As recommended by Booth *et al.* (2016), the review study started with a scoping search in June 2022 to evaluate preliminary sets of databases and search keywords and to examine the range of literature about engineering students' engagement for sustainability. The initial scoping search also enabled us to become familiar with this topic, to identify preliminary research questions for the full review, to refine search keywords and find appropriate alternatives, to identify databases and to develop and document a search strategy. The search terms were initially discussed among all authors of this study from June to August 2022 and revised accordingly based on the results of four rounds of scoping searches. The final keywords were assessed by a librarian who is an expert in conducting literature reviews.

3.1.2 Search protocol development. The refined search terms are presented in Table 3. In August 2022, the formal literature search consulted the following six databases: (1) Web of Science; (2) SCOPUS; (3) EBSCO host (via Academic Search Complete); (4) ERIC (via ProQuest); (5) IEEE XPlore; and (6) Engineering Village. In addition to helping us locate studies in the engineering field, these databases provided multiple resources, such as journal articles, conference papers and other documents, covering diverse practices, research, projects and concepts related to sustainability in engineering education (Borrego *et al.*, 2014).

3.1.3 Inclusion and exclusion criteria. Several inclusion and exclusion criteria were set up as shown in Table 4 prior to the search. To guarantee the quality of the sources and to keep the number of articles manageable, the search was confined to peer-reviewed journal

Reference	Definition and perspective
Appleton *et al.* (2006)	Characterized through four types of engagement, namely academic, behavioural, cognitive and psychological, rooted relations with family and peers and in school context leading to three main engagement outcomes (e.g. academic, social and emotional). That said, engagement is multidimensional, contextual and outcome oriented.
Case (2007)	Concept of engagement as opposition to the concept of alienation through disconnection. In this sense, alienation is defined as "state or experience of being isolated from a group or an activity to which one should belong, or in which one should be involved" (p. 120), whereas the disconnection is the lack, or absence of relationship(s) to oneself, others, institutions and/ or society. That said, engagement is perceived as the "connection in the context of a relationship which a student desires or expects to belong to" (p. 120).
Krause and Coates (2008)	Engagement as "the extent to which students are engaging in activities that higher education research has shown to be linked with high-quality learning outcomes" (p. 493), highlighting its constructivist nature.
Fredricks *et al.* (2004)	Engagement as a "meta-construct" that aims to explain students' academic success and achievements. That said, engagement is multidimensional that comprises three key dimensions: cognition, behaviour and affect.
Kahu (2013)	Engagement as product of interplay of student internal individual processes, emotions, identity and sense of belonging, effective teaching, relations within social and cultural contexts. That said, engagement is multidimensional and holistic, and characterized through four dimensions: behavioural, psychological, social-cultural perspective and holistic perspective.
Servant-Miklos *et al.* (2023)	"Engagement relates to acting towards sustainable development. By engaging, students take responsibility for sustainable practices in different spheres of their lives" (p. 128), namely private, institutional, professional and political. The engagement spheres are explained from two viewpoints, relational view, which highlights their interconnectedness, opposing to a rational view, with limited mutual influence. The spheres can also be perceived as contexts where students can enact their agentic behaviour towards sustainability.
Wimpenny and Savin-Baden (2013)	Engagement comprises four patterns: (1) inter-relational engagement (i.e. students' commitment to a variety of relationships); (2) engagement as autonomy (i.e. shift from unfamiliarity and self-consciousness to self-sufficiency in learning); (3) emotional engagement (i.e. intra-personal capacities for resilience, commitment and persistence); and (4) engagement as connection and reducing disjunction when dealing with challenges. That said, engagement is multidimensional, and with an inherent polarity, meaning positive experiences tend to strengthen engagement, while negative experiences might weaken engagement or lead to disengagement and alienation.

Table 1.
Syntheses the multiple definitions and perspectives of student engagement in education

Sources: Based on Appleton *et al.* (2006), Case (2007), Krause and Coates (2008), Fredricks *et al.* (2004), Kahu (2013), Servant-Miklos *et al.* (2023), Wimpenny and Savin-Baden (2013); Authors' own creation/work

articles. The time of publication was set to end on 31 August 2022, to ensure that no new articles emerged during our analysis. No lower limit on the time was set, which allowed us to explore the developing understanding of student engagement with sustainability over the past decades.

The search was restricted to article titles, abstracts, keywords and topic searches in the six databases. This resulted in 394 relevant articles. After the removal of 58 duplicates, a total of 336 articles were confirmed for further screening.

Engagement	Characteristics
Intrapersonal engagement	
Engagement as autonomy	Related to cognitive engagement, engagement as autonomy is characterized by aspects of consciousness of the self, such as self-efficacy, self-regulation, self-monitoring, goal setting and a commitment to improvement using different strategies and resources. Engagement as autonomy also reflects motivation and student agency to act in response to contextual conditions, for example by filtering information, recognizing structures or improving knowledge and competency (e.g. disciplinary, and sustainability-related), to address sustainability challenges and problems.
Emotional engagement	Also referred to as affective engagement, emotional engagement appears mostly related to resilience, persistence and the capacity to cope with a lack of relevance or with the drudgery of an activity or task. It manifests through attitudes and behaviours of persistence despite potentially obstructive challenges, confrontations or rejections that one may experience. It also manifests through continuous interest, enthusiasm, enjoyment, valuing of learning and having a sense of belonging. In relation to sustainability, emotional engagement includes how students view their capability, and prospects for the future and respond with emotions like grief, anxiety or hope.
Inter-relational engagement	Inter-relational engagement relates to behavioural and social engagement. The relationships students establish are not only with their peers, teachers and tutors, but also with institutions, family, friends, communities, professionals and their careers. It involves the ways in which students experience the relationships, behaviours and attitudes of others, along with the impacts of these relationships (positive or negative) on student learning. Examples of relevant behaviours include support and recognition from peers, co-construction of meaning, involvement in negotiation and decision-making processes, mutual respect and openness to others, including social and cultural diversity. Inter-relational engagement also relates to a sense of agency and its behavioural component. This aspect can be referred to as behavioural engagement and is characterized by positive conduct, effort and participation in joint action for sustainability. This is the motor that promotes interdisciplinary and transdisciplinary learning as well as openness, all of which are important competencies for sustainability.
Engagement as connection and disjunction	Engagement as connection can align with holistic perspectives on engagement. This refers to the worldviews, values and norms that guide students' actions. The opposite of connection is disjunction, which occurs when students experience alienation, injustice, isolation or challenges in relation to their academic expectations, learning, the world, or their meaning systems and when there is a discrepancy between what is thought, claimed and acted upon.

Sources: Based on Appleton *et al.* (2006), Case (2007), Krause and Coates (2008), Fredricks *et al.* (2004), Kahu (2013), Servant-Miklos *et al.* (2023), Wimpenny and Savin-Baden (2013), Guerra (2017), EU Science Hub (2022), Redman and Wiek (2021) and Verlie (2019); Authors' own creation/work

Table 2. Theoretical framework for student engagement with sustainability

3.2 Step 2: screening and filtering process

The screening process started with the filtering of titles and keywords, leading to the removal of 224 articles due to excluded publication types or topics. This reduced the number of articles to 112. Screening the abstracts of the remaining 112 articles further narrowed the range to 66 articles by excluding 46 articles that concerned primary and secondary

Table 3.
Keywords searched in the databases

BLOCK	KEYWORDS
Block 1	Engagement **OR** involvement **OR** participation
AND	AND
Block 2	Sustain* **OR** SDG
AND	AND
Block 3	Engineering
AND	AND
Block 4	Higher education **OR** HE
AND	AND
Block 5	Student **OR** students

Source: Authors' own creation/work

Table 4.
Inclusion and exclusion criteria

Criterion	INCLUSION	EXCLUSION
Date	Until 31 August 2022	After 31 August 2022
Language	English	Not written in English
Type of manuscript	Journal articles	Works other than journal articles (e.g. articles in conference proceedings, book chapters, etc.)
Type of publication	Research-based journal articles	Works not based on research (e.g. scholarly approaches to teaching and learning, conceptual and position papers, systematic reviews, project reports, white papers)
Topic	Student engagement in sustainable activities or participation in sustainability-related activities, events, etc.	Students' understanding or awareness of sustainability, which do not have explicit references in conceptualizing, describing or research activities aiming to promote student engagement for sustainability
Context	Engineering higher education	Everything outside higher engineering education

Source: Authors' own creation/work

education, other disciplines or other higher-education stakeholders. The full-text reading phase removed 36 additional articles for the reasons shown in Figure 1. In the end, 30 articles were determined to be qualified for content analysis. A flowchart of the searching and screening process is shown in Figure 1.

3.3 Step 3: content analysis, coding process and appraisal

In accordance with the content analysis procedure depicted by Borrego *et al.* (2014), our analysis was carried out using both inductive and deductive approaches. We started by coding the articles in terms of their metadata (i.e. author information, publication source and year), research information (i.e. research objectives, research design, mention of engagement and engineering education context). Following this categorization, the articles were coded using the themes provided by the theoretical framework. The inductive approach refers to the codes that emerged during the coding process, in which new aspects of student engagement with sustainability in engineering education were identified. Table 5 provides the coding themes identified as type of engagement and respective examples of coding.

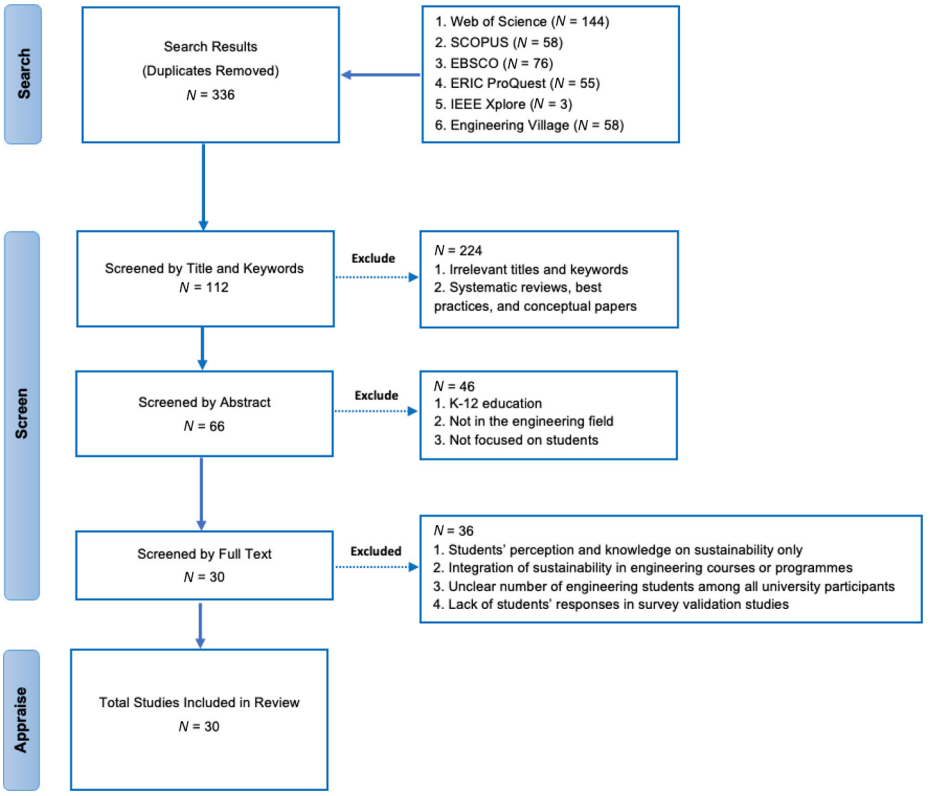

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Figure 1.
Flowchart illustrating the filtering and screening processes

The 30 articles were coded using NVivo 12. The validity and reliability of each study were assessed through inter-coder reliability. From October 2022 to February 2023, authors 1 and 2 independently coded the selected 30 articles, assessed their quality and developed the codebook based on the initial themes. The emerging themes and all open codes from the two authors were checked, revised and discussed through multiple rounds of internal discussion. An overview of selected studies from the coding and appraisal process is shown in the supplementary material.

4. Results

4.1 Metadata

Thirty articles compose the sample included in the review, authored by 100 researchers, published in 12 diverse sources, between the years of 2007 ($n = 1$) and August 2022 ($n = 3$). During this period, the journal with more publications is the *International Journal of Sustainability in Higher Education* ($n = 7$), followed by *Sustainability* ($n = 6$) and *The Journal of Cleaner Production* ($n = 6$). Figure 2 provides an overview of no. of publications per year and per source of publication.

Type of engagement	Examples
Intrapersonal engagement	
Engagement as autonomy	• Knowledge: gaining knowledge on sustainability (e.g. Castro *et al.*, 2020; Watson *et al.*, 2019) • Motivation: motivations to address sustainable issues (e.g. Klotz *et al.*, 2014; Manolis and Manoli, 2021) • Interest: interest in practicing sustainability (e.g. McCormick *et al.*, 2015; Yuan and Zuo, 2013)
Emotional engagement	• Positive attitude: high satisfaction level to sustainable activities (e.g. Castro *et al.*, 2020; Sivapalan, 2017) • Negative attitude towards addressing specific sustainable issues (e.g. Dagiliūtė *et al.*, 2018)
Inter-relational engagement	• Company: Getting support from industrial experts and companies (e.g. Martins Lohn *et al.*, 2017) • Career: Choosing a sustainable working place (e.g. Aleixo *et al.*, 2021)
Engagement as connection and disjunction	• Students' connections and disconnections with courses and projects (e.g. Cogut *et al.*, 2019; Yuan and Zuo, 2013)
Situated engagement*	• Co-curricular activities* (e.g. Cogut *et al.*, 2019) • Courses, lectures and workshops* (e.g. Zeegers and Francis Clark, 2014) • Projects* (e.g. Ngo and Chase, 2021)

Notes: Some codes are defined *à priori* (deductive approach) based theoretical framework (see Section 2.3.) whilst other are defined *à posteriori* (inductive approach), i.e. they emerge during the coding process such as the situational engagement. À posteriori defined codes are identified with (*)
Source: Authors' own creation/work

Table 5. Examples of codes used for the content analysis of the articles selected ($N = 30$)

The countries of affiliation with more publications are respectively, the USA ($n = 11$) and China ($n = 4$). Figure 3 provides an overview of countries and approximate geographic locations of the authors affiliations.

4.2 Intrapersonal engagement

All 30 selected articles included elements that fall within the intrapersonal type of engagement with sustainability. Intrapersonal engagement comprises two subtypes of engagement: engagement as autonomy and emotional engagement. Engagement as autonomy is one of the most prevalent types and comprises elements characterizing knowledge and competencies, motivations and beliefs for sustainability.

*4.2.1 Engagement as autonomy (*n *= 30).* Several studies explored the perceptions, perspectives, awareness or understanding of student engineers about sustainability. These are all categorized as part of the knowledge and competency element to engage with sustainability. In general, it is reported that students in engineering disciplines inquired about SD do show concerns about the environment and the UN's 17 Sustainable Development Goals (SDGs), considering the social aspects of sustainability, linking concepts of sustainability to the engineering profession, and most significantly, building a holistic view of sustainability. In addition, the types of activities they engage in and the sources of information they seek impact the knowledge they acquire and the relationships they establish in the engineering profession. For example, 21 articles argued that student engineers acquire knowledge about all three spheres of sustainability (i.e. environmental sustainability, social sustainability and economic sustainability) by participating in a

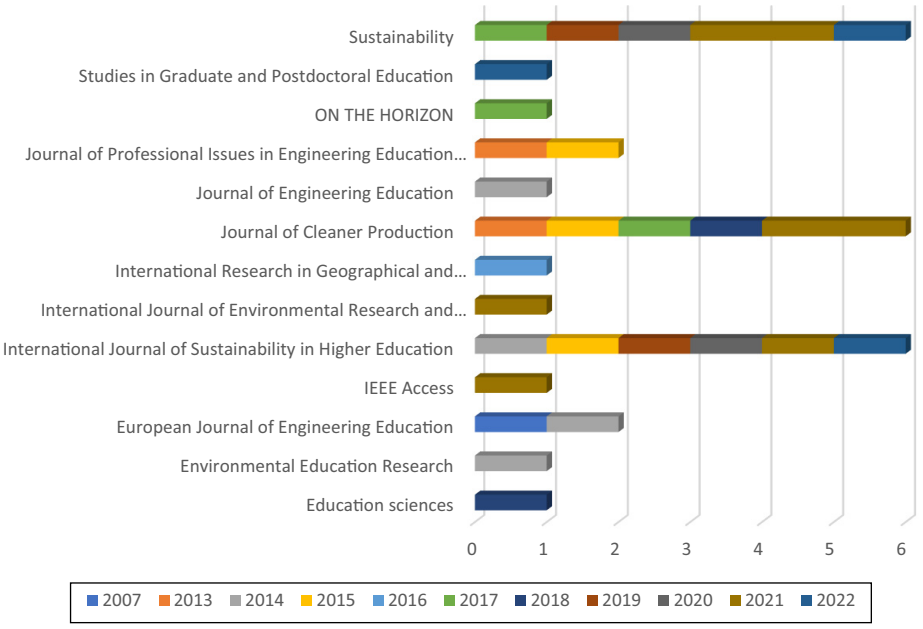

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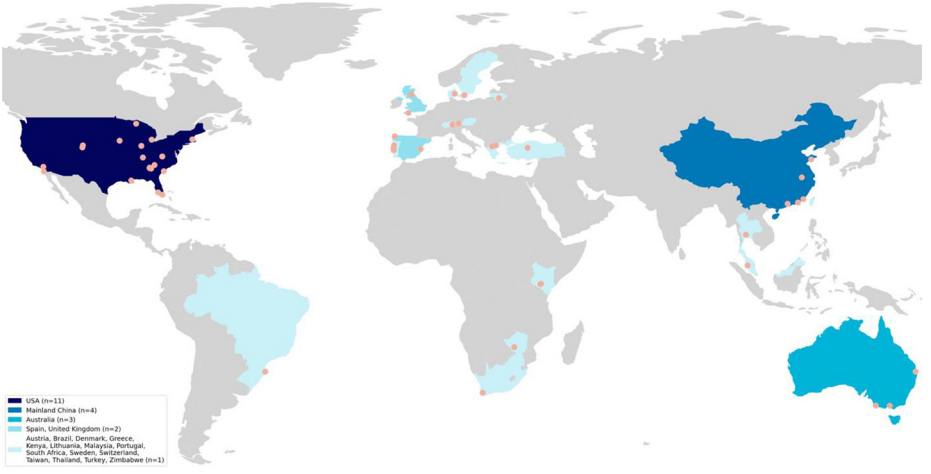
Figure 2.
Overview of no. of publications per year and per source of publication ($N = 30$)



Source: Authors' own creation/work

Figure 3.
Overview of countries/territories and approximate geographic locations of the authors affiliations

variety of related activities such as coursework, projects, campus operations and volunteerism. In turn, this enables them to transfer and apply such knowledge in practice and to actively seek information from diverse sources such as mass media, public forums and university websites.

The results indicate that sustainability-related knowledge reported is environmental sustainability and topics such as climate change, water supply, ecological footprints, biodiversity and resource depletion (France *et al.*, 2022; Janmaimool and Chontanawat, 2021; Ngo and Chase, 2021; Zeegers and Francis Clark, 2014). Thirteen studies found that through participating in sustainability-related activities, students engineer develop multiple sustainability-supporting competencies, including problem-solving competency, collaborative and interpersonal competency, systems thinking competency (critical thinking, analytical skills and interdisciplinary competency) and strategic thinking competency (decision-making, goal setting and creativity). For instance, Castro *et al.* (2020) described student participation in service-learning projects and reported that participating students started to work collaboratively, communicate effectively, design eco-friendly products, propose new solutions for planet protection and consider the possibility of a circular economy.

In contrast, Leiva-Brondo *et al.* (2022) pointed out that economic issues are less widely perceived by student engineers, who have limited knowledge of sustainable business principles and the circular economy. The results also show that students from architecture, civil engineering, environmental engineering and industrial engineering have better perception of SD and adopt more practices related to it (Aleixo *et al.*, 2021; McCormick *et al.*, 2015; Ngo and Chase, 2021; Oberrauch *et al.*, 2021; Shealy *et al.*, 2016; Watson *et al.*, 2013). Fewer than half of the articles ($N = 12$) demonstrated student motivation to engage in activities for sustainability. Those that did showed students' intentions to acquire knowledge on sustainability, apply sustainability-related theories in practice, take more responsibility for sustainability, address sustainability challenges and pursue a career related to SD. Three of them, however, described students as less motivated to engage in activities associated with the social dimensions of sustainability, such as poverty, opportunities for underrepresented groups, reducing the use of packaging, social good and the distribution of resources (Haase, 2014; Klotz *et al.*, 2014; Yuan and Zuo, 2013). Furthermore, 12 studies reported student interest in practicing SD, and five articles indicated improvement in students' confidence regarding implementing sustainability. As for sustainability-related beliefs, nine studies mentioned that students believe that sustainability would be improved by ESD, more leadership from universities and the government, a greater emphasis on environmental issues, improvements in social responsibility and quality of life and engineering solutions. For example, Klotz *et al.* (2014) claim that students are more likely to choose engineering career paths if they enable them to address energy-related issues, water supply and opportunities for future generations. Figure 4 illustrates the codes regarding engagement as autonomy and respective frequencies.

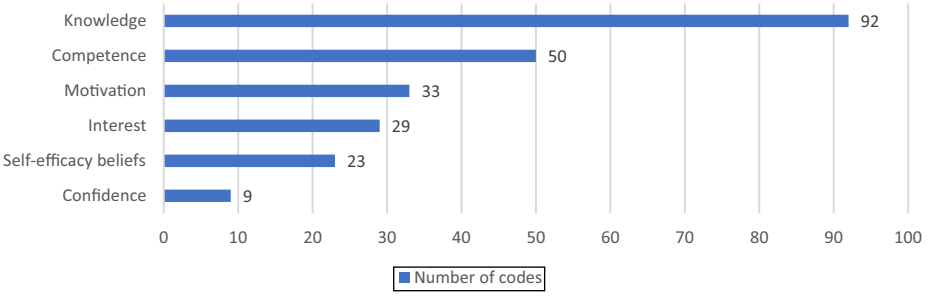


Figure 4.
Engagement as autonomy characterized as knowledge, competence, motivation, interest, self-efficacy beliefs and confidence (total no. codes = 236)

Source: Authors' own creation/work

4.2.2 Emotional engagement (n = *15)*. Emotional engagement is primarily related to affective aspects of learning and is characterized, for example, by emotions, attitudes and behaviours. In the articles analysed for this review, the focus is primarily on student engineers' attitudes, whether positive or negative, along with the importance they attributed to sustainability and their satisfaction with sustainability education. Ten of the fifteen articles addressing this topic suggest that students recognize the concept of sustainability and the importance of related activities as part of the formal curricula and that they view the incorporation of sustainable practices on campus as highly important. The analysis in these articles also indicates that some sustainability topics, especially regarding the environment (e.g. biodiversity, consumption of materials and resources, environmental protection and energy efficiency) and society (e.g. life for future generations, improvement of quality of life and ethical principles), are perceived as important by engineering students both in the present and for their futures. In terms of attitudes, three studies reported student satisfaction with sustainability activities and SD education as well as student willingness to deal with sustainability challenges (Castro *et al.*, 2020; Sivapalan, 2017; Watson *et al.*, 2013), whereas seven studies indicated negative student attitudes towards learning about sustainability (McCormick *et al.*, 2015; Murray *et al.*, 2014) and addressing specific sustainability issues, including maritime disasters, pollution, social issues and more (Dagiliūtė *et al.*, 2018; Leiva-Brondo *et al.*, 2022; Watson *et al.*, 2013). Furthermore, students reported to be dissatisfied with the performance of their institutions and with the level of integration of SD into engineering curricula (Dagiliūtė *et al.*, 2018; Yuan and Zuo, 2013). Figure 5 illustrates the two main codes regarding emotional engagement and respective frequencies.

Sanganyado and Nkomo (2018) is the only article with explicit reference to emotional engagement. These authors state that "when a student considered the online activity highly important, they become cognitively and emotionally engaged" (p. 9). The emotional engagement is not further explored but rather related with importance students give to the task. There is no reference to strong feelings towards something, or someone. Emotional engagement for sustainability in the studies here reviewed are mainly attitudinal, and do not refer to emotions such as fear, anxiety, grief, happiness, hope (Verlie, 2019), and the role they play in meaningful and transformative learning towards sustainability, where values are built, the ability to identify responsibilities is developed and the capability of coping and outlook is enhanced, emotional balance is promoted and leadership for change is promoted (Dunlop and Rushton, 2022; Grund *et al.*, 2024; Cristóvão *et al.*, 2023).

4.3 Inter-relational engagement (n = *20)*

Two-thirds of the selected studies (*n* = 20) described how engineering students interrelate with their careers, teams, industries, friends and family, faculty, staff, local communities,

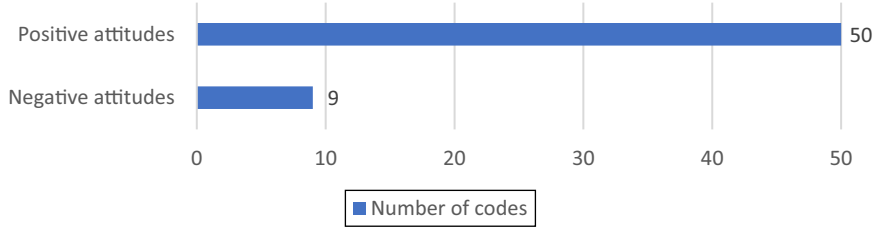


Figure 5. Emotional engagement coded as student positive attitudes and negative attitudes towards sustainability (total no. of codes = 59)

Source: Authors' own creation/work

institutions and other organizations. In this type of engagement, students' relationships with their own careers occurs with a particularly high frequency, with 11 studies indicating that students not only decide to set sustainability-related career goals and practice sustainability in their future career path but also tend to select a sustainable working space. In team settings, three studies reported on students' collaboratively solving real-life sustainability problems, fostering a positive team atmosphere, developing common knowledge and meanings and sharing feedback. For example, Manolis and Manoli (2021) presented students' involvement in ten ecological projects and found that students were interested in informing their peers about SDGs. In addition, students took a moderate level of initiative within their teams towards overcoming obstacles and fostering common goals. Figure 6 illustrates inter-relational engagement as student relations regarding their career, university (incl. peers, teachers, etc.), family, local community, faculty staff and companies, which strengthen their sustainability education.

Student engineers can make positive contributions to their situated environment by disseminating sustainability knowledge to their family and friends or addressing sustainability issues for local communities through project work (Manolis and Manoli, 2021; Ngo and Chase, 2021). The diverse types of inter-relational engagement coded in the analysis highlights the systemic relationships the individual established and participates in acting for sustainability. Whilst intrapersonal engagement is about the individual "self", the inter-relational engagement refers to the relationships the individual establishes with its surrounding. Therefore, one does not engage and act for sustainability in isolation, and the sense of belonging, community, educational or otherwise, is strongly emphasize as a space to co-learn, co-create and co-transform (see for example, Holst, 2023; Ansell *et al.*, 2022; Bakırlıoğlu and McMahon, 2021).

*4.4 Engagement as connection and disconnection (*n = *9)*

A plurality of studies on this topic ($n = 9$) reported positive impacts on student learning outcomes after they attended sustainability-related courses and projects. These studies reported that students build connections among the three dimensions of sustainability in addition to imparting values and beliefs related to sustainability. However, three studies

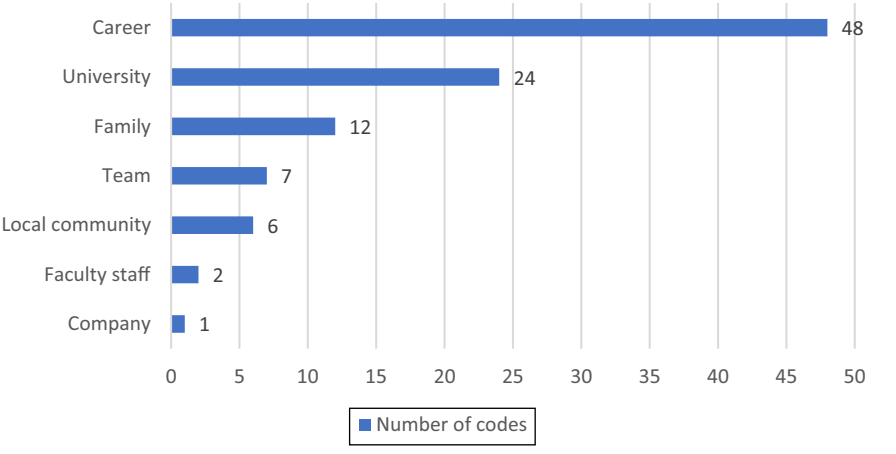


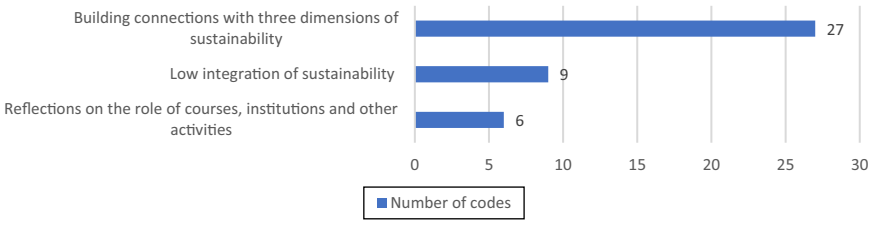
Figure 6.
Inter-relational engagement coded as student relations regarding career, university, family, local community, faculty staff and companies (total no. of codes = 100)

Source: Authors' own creation/work

specified that only a small number of students took the initiative in attending courses that specifically addressed topics of sustainability (Cogut *et al.*, 2019; Qu *et al.*, 2020; Yuan and Zuo, 2013) (Figure 7). Moreover, four articles mentioned the low insertion level of sustainability in engineering courses (Aleixo *et al.*, 2021; France *et al.*, 2022; Martins Lohn *et al.*, 2017; Sivapalan, 2017), and one article reported a preference to engage with activities outside the formal curriculum (Aleixo *et al.*, 2021). Most of these studies took a quantitative approach, lacking the necessary explanation of why such disconnection occurs. However, five articles did demonstrate student reflections on the roles of courses, institutions and other activities (Aleixo *et al.*, 2021; Murray *et al.*, 2014; Qu *et al.*, 2020; Yuan and Zuo, 2013; Zeegers and Francis Clark, 2014) (Figure 7). For example, in Yuan and Zuo's (2013) study, students agreed that their university should prioritize sustainability in campus growth and planning and should also play a role in promoting social good and supporting the staff in sustainable solutions.

4.5 Situated engagement (n = *19)*

In our work, situated engagement is a category that emerged from the open coding processes. We propose recognition of this as a type of engagement both because education for sustainability is contextual (Sterling, 1996) and because the contexts in which the activities take place, as well as environmental conditions, might impact student engagement and learning. Overall, the literature on types of engagement does not refer explicitly to situated or contextual engagement; however, this dimension is implicit because each case of engagement and participation must take place in some time and context (i.e. situation). Engagement is contextual and time bound; consequently, the type of engagement depends on the environment or contexts in which students engage. Although there is constant reference to the contexts where engagement takes place, there is not necessarily any discussion or reflection on the impact of those contexts on student learning. For this reason, we have added situated engagement as a new type of engagement. The type of context within which students engage is influenced by structures conditioning their actions and sense of engagement, translating to a higher or lower sense of ownership of learning and therefore a higher or lower level of engagement. In terms of situated engagement ($n = 19$), students primarily engage in formal, curricular contexts, including courses, curricula, projects and co-curricular activities as Figure 8 illustrates.



Source: Authors' own creation/work

Figure 7.
Engagement as connection and disconnection coded as building connections with three dimensions of sustainability, low integration of sustainability and reflection on role courses, institutions and other activities have in contributing to sustainability (total no. codes = 42)

Thirteen out of nineteen studies reported that students attended lectures, training or workshops to learn sustainability-related topics. In addition, they were provided with hands-on activities, exercises, presentations, projects or multiple online activities within these courses. At the project level ($n = 4$), students participated in projects outside the professional curriculum systems, such as service-learning projects (Castro *et al.*, 2020; Ngo and Chase, 2021), ecological projects (Manolis and Manoli, 2021) or interdisciplinary sustainability projects (Schäfer and Richards, 2007), to broaden their knowledge and experience. Co-curricular activities included activities, programmes and learning experiences connected to or mirroring the academic curriculum. At this level ($N = 2$), sustainability activities operated within the campus to improve students' awareness of certain sustainability topics, such as recycling (Cogut *et al.*, 2019; Dagiliūtė *et al.*, 2018) and the use of public transportation (Dagiliūtė *et al.*, 2018). Although the remaining 11 studies did not specify the context, some articles made use of surveys designed to investigate students' daily engagement with sustainability (e.g. Aleixo *et al.*, 2021; Janmaimool and Chontanawat, 2021; Martins Lohn *et al.*, 2017; McCormick *et al.*, 2015).

Situated engagement aligns with intrapersonal dimension by emphasizing activities and formal learning spaces, with strong focus on developing propositional knowledge about and for sustainability. Formal education tends to emphasize cognitive dimension of learning, with structured activities to achieve pre-defined learning outcomes and regulated by policy documents. Non-formal and informal education are as less, or unstructured, and learning is recognized by the learner, and involves cognitive, emotional, social and behavioural elements. It provides spaces for other dimensions of learning like social and emotional, and not recognized as learning within institutional formal educational frameworks and regulations (Johnson and Majewska, 2022). Holistic and emotional responsive educational approaches are claimed to develop competencies requires to act and transform local community and society towards sustainability (Holst, 2023; Ansell *et al.*, 2022; Bakırlıoğlu and McMahon, 2021); therefore bridging, blending and/or intertwining activities from formal, informal and non-informal education have the potential to create learning spaces for sustainability.

5. Discussion, limitations and recommendations

The study proposes a theoretical framework (see Table 2) that aligns literature on student engagement and on education for sustainability, providing descriptions of what characterizes diverse types of engagement for sustainability, and used to analyse research-based articles, allowing to identify the main patterns of student engagement with sustainability in engineering education.

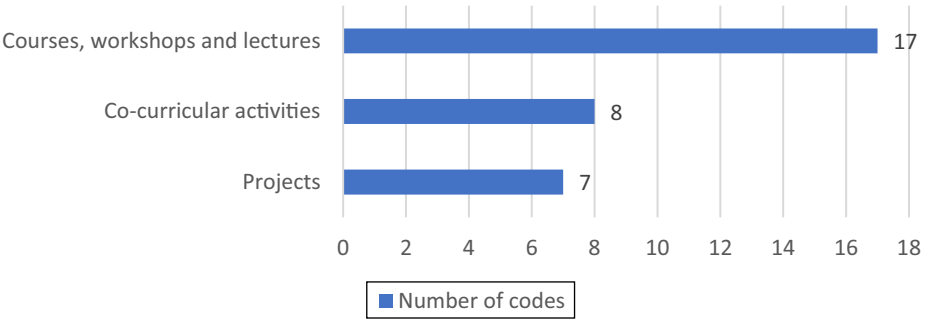


Figure 8.
Situated engagement coded as courses, workshops and lectures, co-curricular activities and projects (total no. of codes = 32)

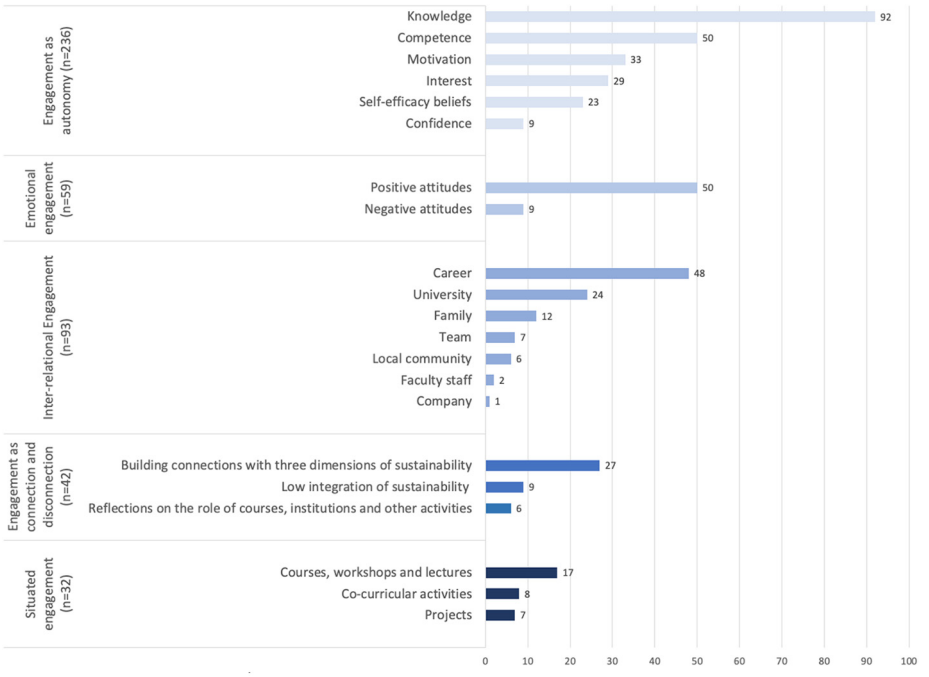
Source: Authors' own creation/work

5.1 Discussion

The engagement of student engineers with sustainability is primarily characterized by activities to acquire knowledge and develop competencies (i.e. engagement as autonomy), with a strong collaborative component (inter-relational engagement) and being contextualized mostly at a curricular level, through courses and project work, along with some co-curricular activities, using student-centred learning approaches (situated engagement) as Figure 9 illustrates.

In addition, the results point to some trends. For example, the research reported primarily focus on student knowledge and competencies, namely sustainable-development topics, and student perceptions, understanding or awareness, and how these are drivers/enablers of action. ESD advocates a "whole person" education, with knowledge ("head as to know"), skills and competencies ("hands as to do"), emotions ("heart as to feel and experience"), values and beliefs ("spirit as to be and becoming") (Hermes and Rimanoczy, 2018; Sterling, 2004). Such a vision incorporates the principles and values of sustainability and moves beyond the social-cognitive foundations of the higher-education paradigm, including socio-emotional dimension of learning (Dunlop and Rushton, 2022; Grund *et al.*, 2024; Cristóvão *et al.*, 2023). However, the results indicate a limited consideration of the "heart" and "spirit" dimensions, given the emphasis on acquisition of knowledge (intrapersonal engagement as autonomy), and formal education contexts for learning (situated engagement).

Furthermore, engagement is not only experiential but also time-bound and contextual, which means that it is dependent on the environmental conditions in which students engage, with their starting points and endpoints. Consequently, the learning achieved through a given activity or situation can be reversed (Case, 2007; Wimpenny and Savin-Baden, 2013).



Source: Authors' own creation/work

Figure 9.
Overview of type of engagement coded in literature and respective frequencies

This is particularly relevant to consider as students are expected to be able to engage with, act in response to and contribute to sustainability in a consistent and continuous way (Holst, 2023). Thus, student engineers' engagement with sustainability should be continuous, fostering the development of a sustainability competence and mindset and making sustainability values a part of the ethos of the professional engineer in the 21st century (Sterling, 2004; EU Science Hub, 2022). In overall, engagement provides conditions for identity development and agency (Guerra *et al.*, 2022; Wimpenny and Savin-Baden, 2013). What is more, the research contexts reported on are still centred around formal higher-education environments and focus on the outcomes of learning rather than on its processes. While educating *about* SD tends to focus on the content, educatio *n* for and *as* SD focuses on the process and quality of the learning experience (Guerra, 2017; Sterling, 2004). ESD is also inter- and transdisciplinary, providing *in situ* experiences for transformative learning. Although some articles provide insight into elements of emotional engagement and engagement as connection (e.g. Aleixo *et al.*, 2021; Haase, 2014), most relied on quantitative approaches and lack in-depth explanations of the values, beliefs and emotions held by students and the ways in which these drive student behaviour. The articles also lack an exploration of the role played by contexts beyond that of formal education, such as non-governmental organizations, activism, volunteerism or self-organized activities (non-formal and informal education spaces and activities), fostering a more holistic student engagement for sustainability (e.g. Holst, 2023; Ansell *et al.*, 2022; Bakırlıoğlu and McMahon, 2021).

5.2 Limitations and recommendations

This study has three main limitations, each suggesting directions for future research. Firstly, the theoretical framework proposes to explain the complexity of student engagement for sustainability and what drives individuals to learn about and act for sustainability in different contexts, for different purposes. We have taken an educational perspective, rooted in socio-psychological aspects, to describe student engagement and to use it as a point of departure to analyse research articles addressing student engineer engagement with sustainability. The theoretical framework for the engagement of student engineers with sustainability calls for further investigation, using a mixed-method approach, in which the different dimensions can each be explored more deeply. This could yield more elaborate explanations in addition to suggesting patterns in the ways in which personal, collaborative and environmental conditions drive students' learning about sustainability.

Secondly, the methodology might impose a limitation on the results, specifically the choice of keywords and the fact that our search was limited to engineering education research on SD. Thus, further literature studies targeting student engagement with sustainability should take a more comprehensive approach by extending the search to include different disciplinary areas, enabling a comparison of the results.

Thirdly, the complexity of the topic, and its holistic perspective, might also limit the results as we focus on a qualitative description of the different typologies and characteristics of engagement, prioritizing breadth over depth. To add the depth, further studies could, for example, focus on one form of engagement and inquire into the ways in which it has been developed in engineering education research for sustainability (e.g. use of comprehensive analysis techniques like data visualization techniques; establishment of correlations between causes and effects).

As for recommendations, the study provides a basis for making the following practical recommendations to support student engagement at different levels:

- at the individual level, by supporting students in formulating individual learning outcomes beyond the formal curricula, providing the opportunity to integrate their personal goals into their formal professional learning;

- at the staff level, by providing professional development whereby educators acquire the knowledge and competencies to design learning environments for the integration of ESD and to build collaborations with local communities for ESD;
- at the level of programmes and curricula, by implementing more problem-oriented, collaborative and contextual learning approaches, in which students engage with local communities to solve complex, authentic problems for sustainability *in situ*; and
- at the institutional and accreditation levels, by recognizing the power of non-formal educational contexts in the achievement of high-quality learning outcomes.

In considering directions for future research about student engineer engagement with sustainability, the following can be recommended:

- grounding and designing studies in educational theories, namely student motivation, identity formation, agency, emotions, etc.;
- using multiple sources of information to capture not only the complexity of learning but also in-depth explanations; and
- focusing on longitudinal and comparative studies, allowing for the exploration of progression and change over time as well as variation across different groups of participants (e.g. with respect to gender, ethnicity, etc.), cultures, countries and institutions.

In addition, some practical recommendations can also be made. For example, to increase student engineer engagement and to promote more holistic sustainability education, institutions and educators should consider designing learning spaces and opportunities to co-create sustainable solutions for local problems through local partnerships (e.g. other education institutions, policy makers, employers, non-governmental organizations, local communities, etc.), and co-transform practices and behaviours, bridging formal, non-formal and informal education.

6. Conclusion

Theory and literature focusing on student engagement emphasizes the role that engagement has in student agency and identity formation, which in turn plays a central role in educating future professionals and citizens to act consistently for sustainability. This inevitably leads to the consideration of whether engineering education institutions and curricula could eventually align better with student learning for sustainability. In addition, the research on engineering ESD needs to achieve higher maturity, by exploring in which ways student engineer agency, professional identity or motivational factors impact their learning in, and for sustainability. The remaining questions are not about the learning principles guiding the designing of these learning environments but rather focus on practice. For example, what are the learning outcomes, and who formulates them? Who formulates the problems, and in what context? Who are the learners and the learning teams (e.g. not only students but also local communities)? What role values and emotions towards sustainability do play in determining students career choices and readiness? These and similar questions continue to call for attention.

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Supplementary material

The supplementary material for this article can be found online.

Corresponding author
Aida Guerra can be contacted at: ag@plan.aau.dk

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