Enhancing sustainability normative and ethics competences in engineering education: insights from a needs analysis systematic literature review

Enhancing Sustainability Normative and ethics Competences in Engineering Education: Insights from a Needs Analysis systematic literature review.

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Abstract

As global challenges intensify, the demand for engineering graduates with sustainability normative and ethical competences has become increasingly urgent. These competences enable individuals to critically reflect on sustainability principles, evaluate ethical dilemmas, and align professional practices with societal goals such as the Sustainable Development Goals (SDGs) and the European Green Deal. The *Transformative Learning for Sustainability and Ethics in STEAM Higher Education (TL-SEEDS)* project addresses this need by identifying the key competences required for engineers to act as ethical change agents in their professions and communities. This paper presents the preliminary findings of an extensive literature review conducted as part of a broader needs analysis. Using the PRISMA 2020 methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), the review systematically identifies and synthesizes existing research on sustainability normative and ethical competences in engineering education. The methodology includes developing a comprehensive search strategy, defining inclusion and exclusion criteria, and extracting key data from selected studies. The literature review focuses on understanding societal, institutional, and professional expectations of sustainability normative and ethical competences in engineering graduates. Key findings highlight persistent gaps in integrating these competences into higher education curricula. Despite widespread recognition of their importance, engineering education often fails to provide students with the tools to navigate complex ethical dilemmas or critically engage with sustainability principles. By focusing on sustainability normative competence, the findings underscore the importance of equipping students with the ability to critically assess sustainability frameworks, anticipate the long-term impacts of engineering decisions, and integrate ethical considerations into technical solutions. Ethical competence, meanwhile, emphasizes the capacity for moral reasoning, empathy, and the ability to address conflicting stakeholder interests in engineering practice. These insights will guide the development of transformative learning strategies tailored to address the identified gaps. The ultimate goal is to create educational environments where sustainability normative and ethical competences are seamlessly integrated into engineering curricula, ensuring graduates are prepared to lead sustainable transitions and ethical innovation. This ongoing research represents a crucial step toward bridging the gap between educational practices and the competencies required for sustainable development. By embedding sustainability normative competence as a core component of engineering curricula, we aim to prepare graduates who can lead responsibly, innovate ethically, and contribute meaningfully to a just and sustainable society.

1 Introduction

As global sustainability challenges become increasingly complex, the role of engineering education in fostering ethical and sustainability-oriented professionals has never been more critical. Engineering graduates must be equipped with sustainability normative and ethical competences that enable them to critically engage with sustainability principles, navigate ethical dilemmas, and align their professional practices with broader societal goals such as the Sustainable Development Goals (SDGs) and the European Green Deal. However, despite the recognized importance of these competences, their integration into higher education curricula remains inconsistent, often leaving students unprepared to address the ethical and sustainability challenges inherent in their field.

The Transformative Learning for Sustainability and Ethics in STEAM Higher Education (TL-SEEDS) project aims to bridge this gap by enhancing ethics and sustainability values learning in STEAM higher education. The project objective is to address the effects of confirmation biases in learning processes and seeks to develop transformative learning (TL) strategies and activities that foster a paradigm shift in values, perspectives, and professional identities rooted in ethics and sustainability. A central research question guiding this initiative is: How can transformative learning strategies effectively mitigate confirmation biases and facilitate the acquisition of sustainability normative and ethical competences in STEAM higher education? Additionally, the project explores how these strategies can be effectively integrated into higher education degree programs.

This paper presents the preliminary findings of a systematic review conducted as part of a broader needs analysis within the TL-SEEDS project. Using the PRISMA 2020 methodology (Page et.al., 2021), the review systematically identifies and synthesizes existing research on sustainability normative and ethical competences in engineering education. The analysis focuses on understanding societal, institutional, and professional expectations regarding these competences and evaluating best practices in transformative learning for sustainability and ethics in higher education.

1.1 Objective

At present, no comprehensive literature review has been identified that systematically maps the ethical and sustainability competencies expected from STEAM graduates. As a result, this review seeks to address the following research questions: What competencies related to ethics and sustainability are currently expected from STEAM graduates by companies, organizations, and society at large? Which ethical and sustainability values are considered essential for STEAM graduates in response to contemporary societal challenges? These questions provide the foundation for the analytical framework used throughout the review and guide the categorization and interpretation of the literature.

2 Methodology

The methodological process was structured in three main stages: identification and screening of relevant literature using the PRISMA 2020 framework; definition of analytical categories based on research questions; and content analysis and interpretation of selected papers.

2.1 Literature Identification and Screening

A systematic review was conducted following the PRISMA 2020 guidelines, which provide a detailed checklist and flow diagram to ensure transparency and reproducibility. Selection criteria were defined according to relevance to the project's objectives and the academic quality of the sources, with only peer-reviewed journal articles being considered. The search was restricted to publications written in English or Spanish and indexed in the Web of Science (WoS) and SCOPUS databases. The focus was placed on literature addressing sustainability and ethics education in engineering and architecture within higher education contexts.

The search strategy, which was applied to article titles, abstracts, and keywords, was developed through the formulation of a set of keywords aligned with the goals of the TL-SEEDS project. The terms included: *"Higher Education – STEAM* Education – engineering education – architecture education – Sustainab* values – ethic*."* Boolean expressions were defined as follows: *(("higher education" AND (steam OR stem)) OR "engineering education" OR "architecture education") AND ("sustainab* values" OR ethics").

To ensure the quality of resources the number of citations was used according to the next criteria:

- Publications before 2018: number of citations >= 35
- Publications from 2019 to 2021: number of citations >= 15
- Publications from 2022 to 2024: number of citations >= 5

The next step was to remove the duplicate articles from the two databases. Finally authors read carefully the abstracts of each reference (each reference was analysed by two researchers) to validate the relevance of the paper in relation to the research questions.

2.2 Definition and Validation of Analytical Categories

Analytical categories were proposed based on the main research questions and iteratively refined through collaborative discussion among the research team. Validation was carried out by having two researchers independently code five selected papers, which were then exchanged for cross-validation. This procedure allowed for the identification of categories requiring greater specificity or clarity, which were subsequently adjusted.

2.3 Content Analysis and Interpretation

Each researcher was assigned fifteen articles for in-depth qualitative analysis. Coding was carried out using ATLAS.ti software, facilitating the systematic categorization of relevant text excerpts according to the predefined analytical framework. Once coded, the content for each category was aggregated and subjected to preliminary interpretation using an artificial intelligence tool trained for content synthesis. For each category, the AI tool received the following instruction: *"We have conducted a literature review using ATLAS.ti software. I'm attaching the codification results for the category [name of the category], which gathers information on [definition of the category]. Summarize the results of the categorization made by*

ATLAS.ti.". The AI-generated summaries were subsequently reviewed and refined by the research team to ensure alignment with the original evidence and maintain analytical consistency across categories.

3 Results

3.1 Articles identification.

Figure 1 illustrates the results of the article selection process based on the PRISMA 2020 methodology. An initial pool of 2,797 articles was retrieved from SCOPUS and 290 from Web of Science (WoS). Following the application of the predefined inclusion and exclusion criteria, a total of 89 articles were selected as relevant for the literature review.

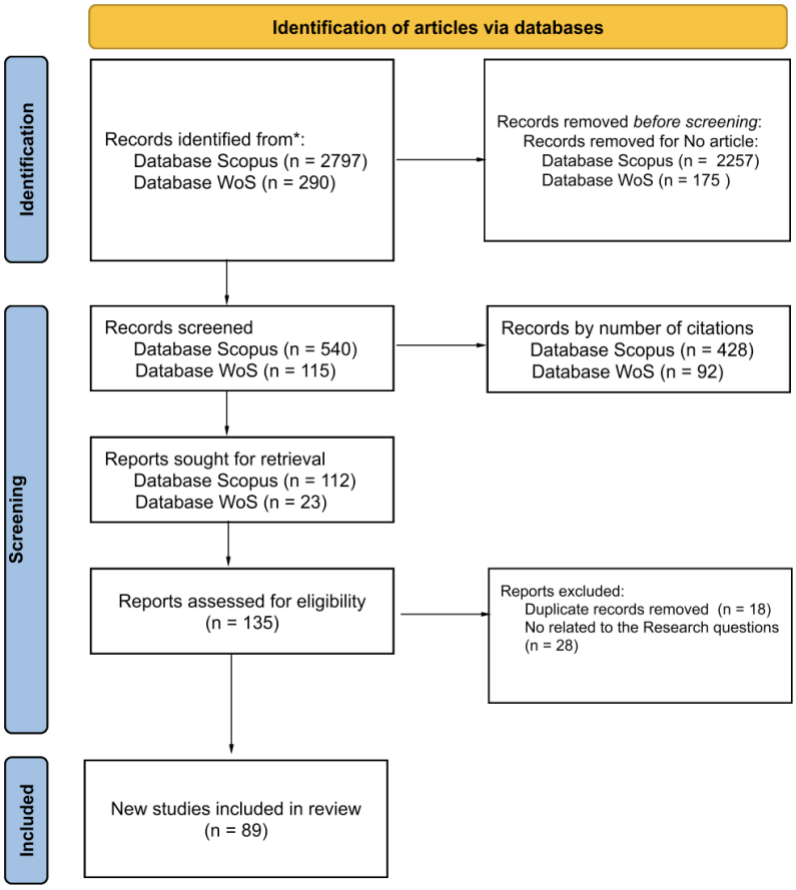

Figure 1: PRISMA 2020 methodology process and results

3.2 Analytical Categories

The identification and validation of 14 key analytical categories are presented in Table 1. This table includes the code, name, and definition of each category, providing a structured framework for the subsequent coding and analysis of the selected literature.

Table 1: Analytical categories coding and description

Code	Name	Definition (Information gathered by the category)
SVC	Sustainable Values Competence	Competencies related to sustainability values. Identifies elements such as: definitions of competencies in values, specific knowledge associated with these competencies, and skills or aptitudes resulting from their acquisition
ETC	Ethics Competence	Ethical competencies. Identifies elements such as definitions of ethical competencies, specific knowledge associated with these competencies, and the skills or aptitudes resulting from their acquisition
RVC	Requirements in Sustainable Values Competence	Specific requirements expected of graduates or professionals regarding competencies in sustainability values. This includes: key knowledge, specific skills, personal values and attitudes and examples of job descriptions or professional profiles that explicitly reference these requirements
REC	Requirements in Ethical Competence	Specific requirements expected of graduates or professionals regarding competencies in Ethics. This includes: key knowledge, specific skills, personal values and attitudes and examples of job descriptions or professional profiles that explicitly reference these requirements
PVC	Pedagogy for Sustainable Values Competence	Teaching methods, instructional strategies, and educational frameworks that aim to foster the development of sustainability values competence. It includes approaches that address how learners are guided to understand, internalize, and apply values related to sustainability in decision-making and behaviour
PEC	Pedagogy for Ethics Competence	Teaching methods, instructional strategies, and educational frameworks designed to develop ethical competence. It includes approaches that aim to help learners identify, analyse, and respond to ethical dilemmas. The focus is on pedagogical practices that promote the understanding and application of ethical principles, values, and frameworks, enabling learners to make responsible decisions in diverse and complex contexts
AVC	Assessment of Sustainable Values Competence	Methods, tools, and frameworks used to evaluate the development and integration of sustainability values competence in learners. It includes approaches to assess how effectively learners understand, internalize, and apply sustainability-related values in their thinking and behaviour. The emphasis is on assessing not only knowledge but also attitudes, behaviours, and decision-making aligned with sustainability principles
AEC	Assessment of Ethics Competence	Methods, tools, and approaches used to evaluate the development of ethical competence in learners. It focuses on assessing their ability to identify, analyse, and respond to ethical issues and dilemmas in a thoughtful and responsible manner. The goal is to assess both cognitive and affective

		dimensions of ethical competence, including attitudes and behaviours
TFL	Transformative Learning	Explicitly mention transformative learning as an educational process in which students undergo profound changes in their perspectives and understanding.
CGB	Cognitive Biases	Presence and impact of cognitive biases. This category also considers situations in which these biases emerge during learning and their relationship with students' level of maturity.
EMO	Emotional implications	Emotional well-being and the role of emotions in learning.
STH	Demanding stakeholders	Identification of the entity that requests the introduction of Sustainability Values Competences and/or Ethical Competences or the entity where they have been introduced.
GEA	Gender analysis	Gender issues and refers to the socially constructed roles, identities, and expectations assigned to individuals based on perceived or self-identified gender.
TER	Teachers Role	The role of educators in facilitating the development of sustainability values and ethical competence in learners. It examines teachers' capacities, training needs of educators to enhance their ability to design, deliver, and assess pedagogical approaches as well as the institutional support required.

3.3 Content analysis and interpretation

The 89 articles were coded using Atlas.ti and, where applicable, categorized according to three dimensions: Region, Discipline, and Scope (see Table 2). The majority of the literature is situated within Anglo-Saxon contexts, particularly the United States, the United Kingdom, and Australia, and primarily focuses on the field of Industrial Engineering. In terms of scope, most articles address ethics and sustainability competences at the institutional or degree program level. In contrast, subject-specific case studies are less frequently represented, both in terms of the number of articles and the volume of associated codes.

Table 2: Classification of references

Ambit	**Number of articles (% from total)**	**Number of codes (% of total) /codes per article**
Region	Anglo-Saxon 26 (29%) Europe 4 (4%) Asia 4 (4%)	Anglo-Saxon 307 (41%) / 12 Europe 42 (6%) / 11 Asia 24 (3%) / 6
Discipline	Industrial Engineering 15 (17%) ICT Engineering 4 (4%) Civil Engineering 3 (3%) Other degrees 9 (10%)	Industrial Engineering 142 (19%) / 9 ICT Engineering 21 (3%) / 5 Civil Engineering 8 (1%) / 3 Other degrees 88 (12%) / 10
Scope	University 14 (16%) Degree 14 (16%) Subject 7 (8%)	University 228 (30%) /16 Degree 106 (14%) / 8 Subject 58 (8%) / 8

The quantitative coding results of the 89 analysed articles across 14 categories are presented in Figure 2. The most frequently coded category relates to Ethics, with a total of 544 instances, significantly surpassing

Sustainability Values, which received 102 codes. Notably, many articles discussing sustainability values often frame them through the lens of ethics, suggesting a strong conceptual overlap. Within the Ethics domain, the category Pedagogy for Ethics Competence (PEC) emerged as the most prominent, with 224 codes, followed by Definitions of Ethics Competence (ETC) with 173 codes, and Requirements for Ethics Competence (REC), explicitly addressing the need for ethical capacities, with 123 codes.

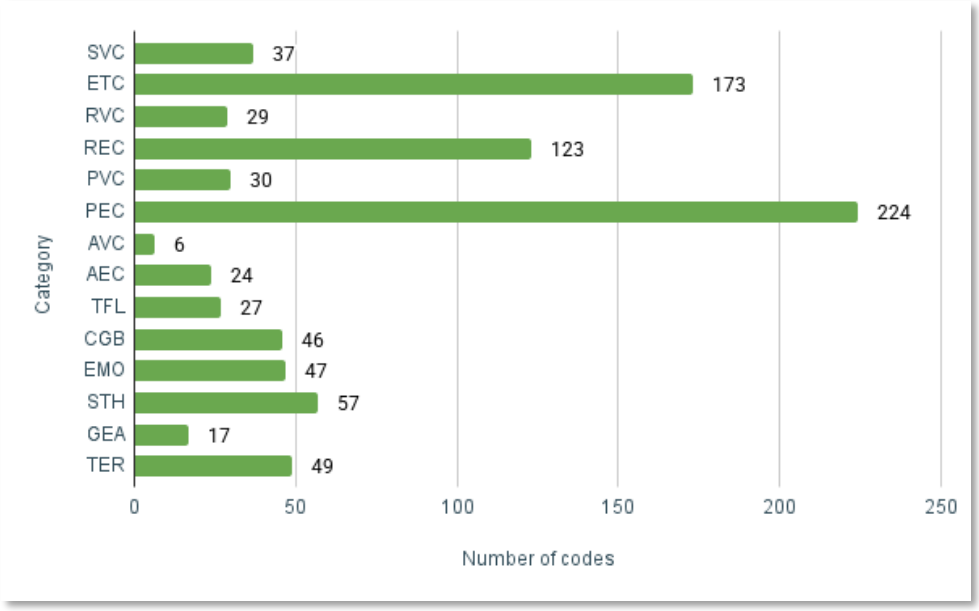

Figure 2: Number of codes per category

Table 3 presents qualitative insights for the most frequently coded categories, serving as illustrative examples of the thematic depth and variation observed in the analysis.

Table 3: Summaries of the coding for most coded categories

Code	Definition (Information gathered by the category)
ETC	ETC includes three dimensions: (1) strong normative foundations rooted in justice, integrity, and responsibility; (2) cognitive knowledge of ethical theories, frameworks, and sociotechnical contexts; and (3) practical skills such as ethical reflection, moral judgment, and decision-making amid complexity.
REC	Four core requirements for ethical competence in STEAM fields are outlined: theoretical knowledge (including ethical reasoning, awareness of social impacts, and familiarity with codes of conduct), practical skills (involving ethical decision-making under ambiguity, stakeholder negotiation, and reflective practice), personal dispositions (such as integrity, empathy, and responsibility toward the public good), and professional expectations. Ethical competence is increasingly linked to roles involving risk governance, social impact, and interdisciplinary collaboration.
PEC	Case-based, service, and project-based learning foster active engagement with real ethical dilemmas, while dialogical methods promote critical reflection. Ethics is best integrated across curricula rather than confined to standalone courses. Interdisciplinary teaching teams, combining technical and ethical expertise, enhance learning through diverse perspectives. Recommended content includes moral theories, professional codes, ethical heuristics, and STS readings. Course models vary, with integrated and hybrid approaches offering

	sustained ethical exposure. Core learning objectives focus on stakeholder analysis, critical reflection on values, and ethical reasoning as an ongoing process, emphasizing ethics beyond rule compliance and toward moral inquiry within professional practice.

4 Conclusions

This literature analysis reveals a multi-dimensional and deeply interwoven framework for cultivating ethical and sustainability competences (SVC and ETC) in STEAM education. Across the sources, there is clear consensus that fostering these competencies requires more than theoretical knowledge—it demands an integration of values, emotional engagement, and practical, context-sensitive learning. Core dimensions such as ethical reasoning, justice, responsibility, and critical reflection are consistently emphasized, highlighting the transformative potential of education when it addresses both personal and societal values. Experiential and participatory pedagogies, including case-based learning, reflective writing, and interdisciplinary collaboration, emerge as powerful tools to deepen ethical awareness and embed sustainability principles. However, persistent challenges remain: assessment practices are inconsistent, faculty often lack training, and systemic biases—cognitive, emotional, and institutional—limit inclusive, reflective learning environments. Gender and affect further shape student engagement, underscoring the need for equitable, emotionally attuned pedagogies. Preparing students for the ethical complexities of sustainability transitions thus requires a shift from fragmented instruction toward holistic, integrated, and emotionally literate education. Educators play a pivotal role in this transformation and must be supported institutionally to cultivate reflective, responsible, and future-oriented professionals. Overall, the findings call for sustained efforts to embed ethics and sustainability not just in curricula, but in the culture of STEAM education itself.

5 Next steps

Findings from the scientific literature review will be complemented by an analysis of grey literature and validated through engagement with relevant stakeholders via interviews, questionnaires, and focus groups. This multi-method approach will culminate in a final triangulation of results, enabling a robust and comprehensive identification of the key needs, barriers, and opportunities for effectively embedding sustainability values and ethics into the learning pathways of future graduates.

References

Page, M.J. et.al., 2021. Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E. and Chou, R., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj*, *372*. doi: https://doi.org/10.1136/bmj.n71