Transformative learning for sustainability and ethics in STEAM higher education: a systematic review of best practices

Transformative Learning for Sustainability and Ethics in STEAM Higher Education: A Systematic Review of Best Practices

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Abstract

The global urgency for sustainability highlights the need for higher education to cultivate transformative learning (TL) approaches that empower graduates to act as ethical and proactive agents of change. The project *Transformative Learning for Sustainability and Ethics in STEAM Higher Education (TL-SEEDS)* addresses this challenge by investigating how student's cognitive biases, such as confirmation bias and cognitive dissonance, often hinder their capacity to critically reflect and integrate sustainability and ethical competences into their professional and personal contexts. This study presents a systematic literature review conducted under Objective 2 of TL-SEEDS, aiming to analyse state-of-the-art TL practices in higher education. The review methodology was informed by the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology principles, drawing from previous research to tailor the process to the specific aims of the project's Objective 2. Supported by AI-enhanced search strategies, the review synthesized studies on TL processes, cognitive biases, and emotional wellbeing, with particular focus on technological disciplines. It identifies key strategies such as fostering agency, promoting interdisciplinary collaboration, and engaging students in real-world sustainability challenges, all aimed at counteracting cognitive biases and enhancing ethical competence. The importance of creating structured spaces for emotional engagement within TL experiences is also emphasized. Through this research, TL-SEEDS lays the groundwork for innovative solutions that bridge learning gaps.

1 Introduction

1.1 Rationale

Climate breakdown, biodiversity loss, widening inequalities and rampant misinformation demand that higher-education—especially STEAM—shift from content-centred teaching to approaches that nurture

ethical awareness, emotional literacy and sustainability competences. Conventional "value-neutral" curricula leave graduates ill-equipped to confront wicked problems such as climate justice or algorithmic bias. Echoing the EU Recommendation on learning for the green transition (Council of the European Union, 2022), recent scholarship urges participatory, emotionally safe and transdisciplinary learning environments rooted in Transformative Learning (TL).

TL (Mezirow, 2000) reframes world-views through critical reflection, dialogue and emotion. Updated models show that emotions – from discomfort and eco-anxiety to awe and solidarity – catalyse TL's five meta-phases: novel experience, reflection, social exchange, action shift and meaning shift. Yet systematic reviews (Coffey, Berlach and O'Neill, 2021; Grund, Brock and Wiek, 2023) reveal that most higher-education interventions still ignore emotion theory, cognitive bias and discipline-specific cultures that prize objectivity. As a result, confirmation bias, dissonance and professional identity defences block the integration of sustainability and ethics into technical practice.

1.2 Research Gap and Objectives

Few studies analyse how TL can be operationalised to dismantle cognitive biases inside STEAM programmes or how to embed structured emotional processing. The Objective 2 (this review) of the research project TL-SEEDS aims to map current best practices in TL for sustainability and ethics in higher education, with a focus on addressing emotional scaffolding, interdisciplinarity and bias-mitigation. The findings will support a compilation of exemplary case studies for future educational use.

1.3 Conceptual Foundations of Transformative Learning and relevance

Transformative learning involves shifts in both meaning perspectives (worldviews) and meaning schemes (specific beliefs). Mezirow, (1978, 1991) proposed a ten-phase process that begins with a disorienting dilemma, moves through emotionally charged self-examination and dialogue with others, and culminates in the reintegration of new, more inclusive perspectives. Subsequent scholars expanded TL: (Mälkki, 2010) foregrounded the role of subconscious "edge-emotions"; (Dirkx, 2006) emphasized the importance of symbolic and emotional work; (Taylor and Cranton, 2012), along with (Nohl, 2015), highlighted the sociocultural embedding of transformation; and (Grund, Brock and Wiek, 2021) stressed that emotions are pivotal across all phases of transformative learning.

In the field of sustainability education, learners frequently confront unsettling realities that evoke eco-anxiety, guilt, and moral distress. When properly scaffolded, these emotions serve as catalysts for perspective transformation and empower collective action. Effective TL relies on creating safe spaces, fostering authentic dialogue, promoting experiential and community-based learning, and embracing transdisciplinary approaches that honour diverse ways of knowing.

In STEAM fields, which profoundly shape infrastructures and technologies, traditional value-neutral norms often inhibit ethical reflection. TL helps surface and critique disciplinary biases, facilitates identity shifts from "objective technician" to "responsible change-agent," and harnesses emotional engagement to move learners from paralysis to purposeful action. It also fosters the integration of scientific, ethical, cultural, and experiential knowledge essential for systems thinking. In doing so, TL operationalises global policy frameworks such as the European Union's Green Transition (European Commission, 2020) and UNESCO's

Education for Sustainable Development 2030 Agenda (UNESCO, 2020), equipping graduates to innovate with integrity and social responsibility.

2 Methodology

2.1 Literature Identification and Screening

The search strategy, applied to article titles, abstracts, and keywords, was developed based on the main research questions of the TL-SEEDS project. A list of 30 keywords was formulated, and inclusion and exclusion criteria were defined through collaborative discussion among researchers to ensure consistency. Only peer-reviewed research articles were included, while grey literature was reserved for later review.

Structured searches were conducted using adapted queries to match each database's capabilities. In Scopus, three Boolean queries were used, incorporating proximity operators and date restrictions (1999–2025): ALL("Transformative learning" AND (sustainab* OR ethic*) AND (steam OR stem OR "Higher Education") AND (learning W/4 frameworks) AND edu*) AND (PUBYEAR > 1999 AND PUBYEAR < 2025); ALL(("Experiential learning" AND "ethical decision-making") AND (sustainab* OR ethic*) AND (steam* OR stem OR "Higher Education") AND ((learning W/4 frameworks) OR (systems-based W/2 learning))) AND (PUBYEAR > 1999 AND PUBYEAR < 2025); ALL((steam OR stem OR "Higher Education") AND ("Applied ethics" OR "learning tools") AND "Transformative Learning") AND (PUBYEAR > 1999 AND PUBYEAR < 2025).

In Web of Science, queries had to be adapted to the database restrictions. We used: TS=("Transformative learning" AND (sustainab* OR ethic*) AND (steam OR stem OR "Higher Education")) AND PY=(2000-2024); TS=(("Experiential learning" OR "ethical decision-making" OR "learning tools") AND (sustainab* OR ethic*) AND (steam* OR stem OR "Higher Education") AND ((learning NEAR/4 frameworks) OR (systems-based NEAR/2 learning))) AND PY=(2000-2024).

ERIC did not allow proximity searches, so broader queries were applied: "Transformative learning" AND (STEAM OR STEM OR "Higher Education") AND (ethics OR sustainability) pubyearmin:2000 pubyearmax:2024; "Transformative learning" AND ("Computer Science" OR "Informatics" OR "Computing") pubyearmin:2000 pubyearmax:2024, retrieving 186 records. In PubMed, the following query was used: "Transformative learning" AND ((ethic* OR sustainab*) OR "learning frameworks"[Title/Abstract:3]).

All retrieved records were merged, and duplicates were removed using JabRef and Zotero. Entries lacking abstracts were excluded to ensure compatibility with AI-assisted screening.

Title and abstract screening was performed using a semi-automated AI tool (Van De Schoot et al., 2021), following PRISMA standards and ethical AI guidelines (Van Dijk et al., 2023). The AI-tool ASReview, uses active learning to iteratively learn from human input, dynamically reordering the review stack to prioritize the most relevant articles. It applies text mining and statistical weighting (TF-IDF) to support a Naïve Bayes classifier that reorders articles by estimated relevance (Van De Schoot et al., 2021). Final

inclusion decisions were made by human reviewers. Additionally, six manually selected articles were included as positive examples to train the AI relevance algorithm.

To refine article selection, a citation-based quality filter was applied: a minimum of 35 citations for publications before 2018, 15 citations for those from 2019 to 2021, and 5 citations for publications from 2022 onwards. Given the recent nature of TL research, the filter was used selectively when transformative learning concepts were not clearly visible in titles or abstracts.

2.2 Analytical Categories

The analytical categories were initially proposed based on the main research questions and were inspired by prior work conducted by one of the researchers within the RESONATE project[1]. Their refinement and adjustment were carried out by the coordination team of Objective 2 through iterative phases of reconsideration. This approach allowed the categories to be progressively aligned with the specific aims of the TL-SEEDS project, ensuring both conceptual coherence and practical relevance.

2.3 Analysis and Interpretation of the Categorization

Articles were analysed using the Categorization Helper, a customized GPT-based tool trained with the analytical categories. The Helper read full-text PDFs and identified category-relevant excerpts. Absences of relevant content were also recorded to ensure transparency. Researchers manually uploaded each article, and a sample of five outputs was reviewed to verify the accuracy and consistency of extracted citations.

This process produced a traceable, article-by-article codification that enabled the next phase. For each category, the Categorization Helper received a specific synthesis prompt: *"I have conducted a literature review using this Categorization Helper. I am attaching the coding results for the category [name of the category] which gathers information on [definition of the category]. Summarize the results of the categorization made by this Categorization Helper".* The summaries were later reviewed and refined to ensure alignment to the original evidence and keep consistency across categories.

3 Results

3.1 Literature Identification and Screening

The structured search retrieved 1,723 records from Scopus, 149 records from Web of Science, 186 records from ERIC, and 86 records from PubMed, resulting in a total of 2,144 initial entries. Deduplication removed 111 duplicates (78 with JabRef and 33 with Zotero), remaining 2,033 unique records. Subsequently, 47 records lacking abstracts were excluded to ensure compatibility with the AI-tool, leaving a final dataset of 1,986 articles. During the title and abstract screening phase using ASReview, the predefined stopping criterion was reached after reviewing only 41.65% of the records, reflecting high AI efficiency. As a result of this initial screening, 250 articles were selected for further detailed analysis. Finally, after the application

[1] https://www.isglobal.org/ca/-/resonate-resilience-nature

of the citation-based quality criteria, 155 articles were retained as the final selection for subsequent stages of the study.

3.2 Analytical Categories

Table 1 presents the 11 analytical categories, specifying their names and definitions. They structured the coding and analysis of the selected literature and constituted the foundation for training the AI Categorization Helper.

Table 1: Analytical categories coding and description

Num	Name	Definition
1	TL Strategy or Approach	Refers to the transformational learning framework guiding the study, such as Mezirow's Transformative Learning, Experiential Learning Theory, Theory U, or Pedagogy of Discomfort. This category identifies the educational theory or model underpinning the intervention or analysis.
2	Learning Context	Specifies the educational environment where the learning intervention took place, including higher education, STEAM programs, informal education settings, nature-based learning, urban education, or intergenerational contexts. It identifies the situational setting and target audience of the study.
3	Emotion- related Focus	Refers to the emotions that are actively engaged or examined within the learning process, such as hope, eco-anxiety, empathy, resilience, discomfort, and joy. It identifies emotional dimensions seen as central to transformational learning outcomes.
4	Bias/Mental Model Component	Highlights whether the study addresses cognitive biases (e.g., confirmation bias) or promotes mental model shifts, including cognitive dissonance or belief revision. This category identifies intentional strategies to confront or alter participants' pre-existing mental frameworks.
5	Sustainability/ Ethical Theme	Refers to the study's explicit focus on sustainability, justice, or ethical considerations within the learning experience. It identifies efforts to embed ethical reflection and a commitment to societal transformation in education.
6	External Mediators Present	Indicates the presence of external mediators like nature connection, intergenerational dialogue, empathy, agency, or reflective practices that facilitate transformational learning. It identifies external elements that catalyse or deepen the learning experience.
7	Transformation Outcome	Refers to any reported personal or collective change resulting from the intervention, such as increased agency, behavioural shifts, mindset evolution, or enhanced self-efficacy. This category identifies tangible impacts attributed to the learning process.
8	Barriers/ Challenges Identified	Specifies obstacles encountered during the learning intervention, which may be structural (institutional or systemic barriers), emotional (affective resistance), or epistemic (knowledge-related hurdles). It identifies factors that hinder the intended transformation.
9	Methodology	Refers to the research method used, including qualitative, mixed-methods, longitudinal studies, or others. It identifies how data were collected, analysed, and interpreted to draw conclusions.
10	Intervention Type	Specifies the format of the learning intervention such as workshops, course modules, lecture series, or fieldwork activities. It identifies the practical structure used to implement transformational learning strategies.
11	Keywords	A selection of no more than five keywords that encapsulate the core themes or topics of the study. It identifies concise conceptual tags to aid indexing and retrieval.

3.3 Analysis and Interpretation of the Categorization

Table 2 provides qualitative insights across all analytical categories, as each category was identified in the coding of at least one of the reviewed articles. The AI-Helper was instructed to cite the specific articles from which the information was derived.

Table 2: Summaries of the coding for the categories

Num	Definition
1	Recent studies have diversified TL strategies by integrating ecological and systemic frameworks. Mezirow's theory has been extended through interdisciplinary approaches addressing socio-environmental transitions. Pedagogy of Discomfort has also been emphasized combining with empowerment strategies. Earlier references remain foundational but are now adapted into broader, transdisciplinary models. The trend highlights a shift towards frameworks that not only foster critical reflection but also embed ecological and social transformation at the core.
2	Learning contexts have evolved towards hybrid and community-based models, implementing interventions blending digital spaces with local fieldwork, enabling deeper transformative engagement. Intergenerational and socio-ecological learning environments have gained importance, offering emotional depth and systemic perspectives. Earlier HE-centered models are now enriched with context-sensitive, participatory learning ecosystems responsive to complex societal challenges.
3	Recent transformative interventions recognize a broader emotional landscape, positioning joy, empowerment, and eco-hope alongside discomfort and eco-anxiety, fostering emotional resilience. Certain collective empowerment emotions have been identified as capable of sustaining transformative processes. Traditional focuses on discomfort as a catalyst are now complemented by positive emotional engagement strategies. Emotions are no longer just triggers for reflection but drivers of long-term agency and sustainable action.
4	TL strategies now tackle cognitive biases through dynamic and participatory methodologies. Gamification has been applied to destabilize confirmation biases and promote flexible thinking. Scenario-based learning has been applied to facilitate epistemic openness. Earlier reliance on critical reflection laid important groundwork, but recent studies emphasize multisensory, experiential disruption as essential for genuine mental model transformation.
5	Recent interventions have expanded sustainability themes to integrate justice, technology, and regenerative thinking, foregrounding ethical AI, decolonial sustainability, and socio-ecological resilience. Contemporary TL increasingly frames sustainability within broader ethical, systemic, and planetary justice frameworks, responding to the urgency of global socio-environmental challenges.
6	External mediators are evolving towards more hybrid and technology-enhanced modalities: Nature connection is introduced through augmented reality to complement traditional field immersion. Reflection, agency development, and empathy remain core mediators but recent interventions emphasize multi-modal engagement, integrating sensory, narrative, and intergenerational elements to catalyse transformative depth across diverse learner groups.
7	Recent studies emphasize both individual and collective transformation outcomes. Participants transition into civic leadership roles post-intervention. Empowered agency, collective activism, and eco-social engagement were key markers of success. Earlier documentation of personal shifts laid critical foundations, but current outcomes reflect broader, systemic engagements extending transformation beyond the classroom and into active societal participation.
8	Emerging barriers highlight the tension between technological mediation and transformative depth. Identified barriers are: digital fatigue, attention fragmentation, and emotional detachment as significant obstacles in hybrid interventions. Structural inertia remains a historical challenge, but new barriers demand adaptive designs prioritizing emotional anchoring and sustained learner engagement across blended environments. Effective interventions now require addressing emotional, cognitive, and systemic barriers simultaneously.
9	Methodological innovation defines current TL research: Participatory action research to embed learners as active co-creators of transformation; Mixed-methods with longitudinal tracking to capture dynamic

Num	Definition
	changes over time. Earlier qualitative traditions provided critical depth foundations. However, contemporary approaches increasingly favor iterative, participatory, and adaptive designs to reflect complex, evolving educational realities.
10	Transformative interventions are increasingly hybrid, intensive, and flexible. "Transformative sprints," short-duration interventions maintaining emotional depth are introduced. Records combine fieldwork with digital reflection hubs to extend experiential engagement. Classic formats like workshops and modules still inform practice, but contemporary models stress multimodal, interwoven structures designed for scalability, agility, and deep emotional-cognitive integration.
11	Recent studies reveal a semantic expansion in transformative learning keywords: "eco-social transition," "regenerative learning," and "environmental justice." has been incorporated, while traditional keywords such as "critical reflection" and "sustainability education" persist. Contemporary indexing increasingly reflects complexity, intersectionality, and systemic transformation, aligning with current socio-ecological challenges and educational visions.

4 Conclusions

This study highlights the growing importance of TL approaches in preparing STEAM graduates to address sustainability and ethical challenges. The scoping review revealed a diversification of TL strategies, with increasing emphasis on emotional engagement, critical consciousness, inter- and transdisciplinarity, and cognitive bias mitigation. Recent practices reflect a shift towards systemic, experiential, collective and emotionally anchored educational models.

All eleven analytical categories were identified across the selected literature, confirming the relevance of the proposed framework. Nature connection, recognized as a key external mediator, and hybrid intervention formats, such as transformative sprints and blended learning experiences, emerged as important elements supporting transformative engagement by means of promoting critical reflection, emotional resilience, and ethical agency. Moreover, outcomes increasingly build on traditional critical reflection by fostering empowered agency, collective activism, and eco-social engagement. Nevertheless, gaps remain, particularly regarding the operational integration of emotion theories or limited cognitive bias mitigation strategies. The findings provide a foundation for developing a curated database of best practices and for guiding future phases of the TL-SEEDS project towards designing transformative educational interventions grounded in ethics, emotional resilience, and systemic thinking.

5 Next steps

Building on the completed literature mapping, the next phase will focus on synthesizing key trends and best practices in transformative learning for sustainability and ethics in STEAM higher education. Critical analysis of selected studies will identify shared approaches, innovations, and gaps. This will be complemented by stakeholder consultations through focus groups. Findings will be compiled in a structured database. This will support the design of future TL strategies within the TL-SEEDS project.

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