SciCultureD

Literature Review on Transdisciplinary Education in HEI

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1. Introduction

The current literature review attempts to gather, compile, and consider the current status of transdisciplinary (TD) education in higher education institutions (HEIs), with a particular emphasis on the disciplines involved, the rationale for their design, the strategies and approaches employed for their implementation, and the difficulties encountered in doing so. This literature review is conducted as part of SciCultureD, an Erasmus+-funded project that continues the work of SciCulture. Both initiatives aimed to address 'wicked' problems[1], aligning their goals with the European Green Deal and the UN Sustainable Development Goals. These objectives are realized through intensive courses and other activities that employ design thinking and creative pedagogies[2] to foster transdisciplinary collaboration and co-creation among participants from diverse backgrounds.

The review will be structured around the following research questions: Which disciplines are most involved in transdisciplinary education? Do they only include the sciences, or do they also include disciplines like the humanities, arts, entrepreneurship, and ethics? What are the driving forces behind the creation of these programmes—are they intended to address complex problems, promote social change, or contribute to global goals such as the Sustainable Development Goals (SDGs)? What particular strategies have been employed to carry out transdisciplinary education, and do these programmes make use of design thinking, arts, and/ or other creative methods? What challenges are frequently faced while implementing transdisciplinary programmes or activities? What could SciCulture/D add to transdisciplinary education?

By tackling these questions, the literature review will help us understand the role TD education could play- and is actually playing- in reshaping higher education to address real-world contemporary challenges, such as combating climate change, enhancing public health systems, or promoting

[1] In their 1973 paper *"Dilemmas in a General Theory of Planning,"* Horst Rittel and Melvin Webber define wicked problems as complex societal challenges that lack clear definitions and definitive solutions. These problems are characterized by the absence of a stopping rule, solutions that are evaluated as better or worse rather than right or wrong, and unique contexts requiring tailored approaches. They often have irreversible consequences and fundamentally differ from solvable "tame" problems in science and engineering (Rittel and Webber 1973).

[2] Chappell et al. (2019, p. 298) define “creative pedagogies” as teaching and learning activities which facilitate urposive and imaginative activity generating outcomes that are original and valuable in relation to the learner”, which include both teacher creativity and teaching for creativity.

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sustainable urban development. Before we discuss the findings of reviewing the literature, we describe the process we adopted to select the relevant literature.

2. Methods

We conducted a search for relevant literature in Scopus in February 2023 without specifying an additional timeframe. The search string used was: "transdisciplinary education + HEI/Higher Education Institutions." This search yielded 126 results. After reviewing the titles and abstracts, we excluded 76 entries that did not match our selection criteria. The excluded articles did not match our focus on transdisciplinary education in Higher education by considering, for instance, transdisciplinary research rather than education, having transdisciplinarity on the margin, treating transdisciplinary education in schools, or employing a transdisciplinary approach to investigate a specific topic or other aspects of HEIs unrelated to education. This resulted in 50 articles proceeding to the second round of screening.

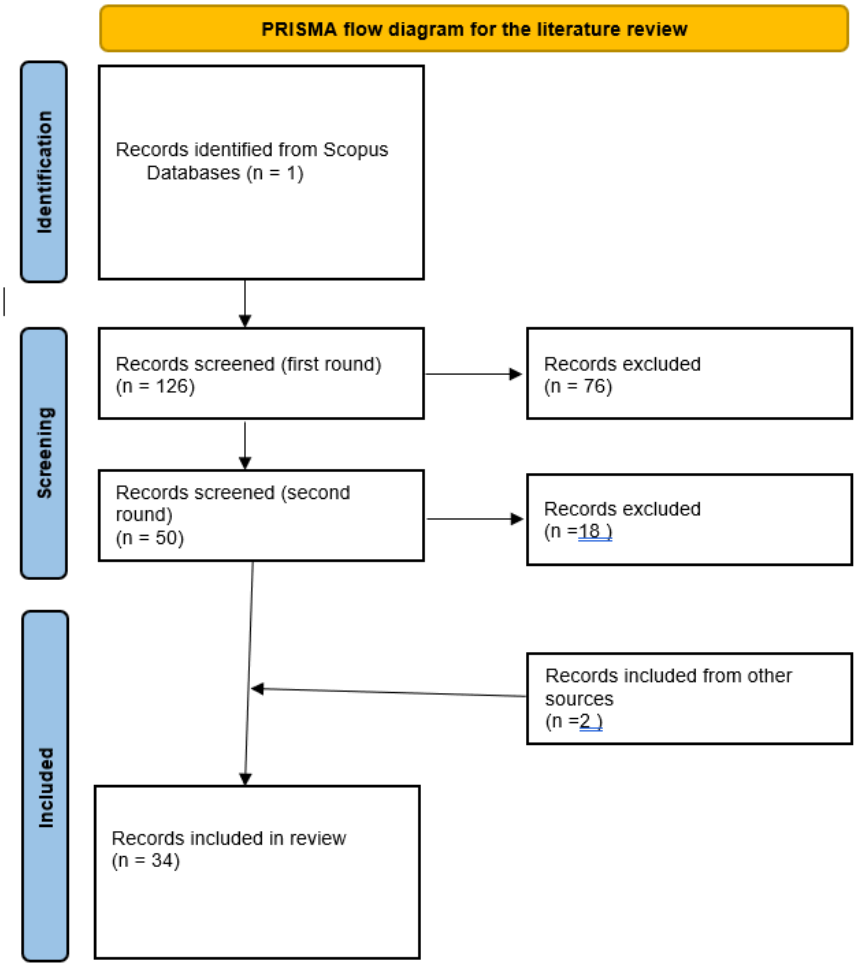
In the second round, we focused on articles that considered transdisciplinary education, involved various disciplines (not just science), explored, implemented, or questioned the approach of embedding transdisciplinarity in HEI education, and adopted transdisciplinary education as a means of addressing wicked problems, such as sustainability. We reviewed the titles, abstracts, and conclusions of the articles, searching for keywords such as *creative*, *art/s*, *sustainability*, and *challenges*. We assigned points to the articles in five areas:

1. **Transdisciplinary Education**: Whether the article or the educational programme it describes is (nearly) entirely about transdisciplinary education (4-5 points), partially about or mentions transdisciplinary education (3-2 points), or not about transdisciplinary education (1 point).
2. **Method**: Whether the article or programme employs creative or somewhat creative methods (5-4 points), barely employs or only mentions creative methods (3-2 points), or does not employ or mention any creative methods (1 point).
3. **Disciplines**: Whether the article or programme brings together 2-3 disciplines or practices from arts, science, humanities, entrepreneurship, and societal engagement (4-5 points); combines 2 disciplines from these areas (3 points if they are from different categories like arts and science, 2 points if from the same area, e.g., both from science); or relies exclusively on one discipline or does not mention any clear disciplines (1 point).
4. **Student-Centred Approach**: Whether the article or the programme focuses on empowering students to act while learning (5-4 points), engages students to some extent or rarely (3-2 points), or is not student-centred at all or provides insufficient information (1 point).
5. **Rationale**: Whether the article or programme has a strong or somewhat strong focus on societal change, social or environmental justice, or sustainability issues (5-4 points); mentions these issues often or occasionally (3-2 points); or rarely or never mentions such topics (1 point).

The articles were divided between two reviewers for this process. After assigning points in the second round, a total of 17 texts were excluded, with one reviewer excluding 10 and the other excluding 7. To validate the results, 8 articles (4 articles per reviewer) were subjected to a third round of

double-checking. This selection included a mix of clearly included and excluded texts, as well as those where we were uncertain, which were re-evaluated by the other reviewer.

Following this, we held a joint meeting to discuss the texts with unclear evaluations. Through this discussion, we decided to include one text that was initially excluded and to exclude two texts that were initially included. The total number of the selected literature is 32 titles. We then incorporated two additional articles recommended by core SciCultureD team members, who are recognized experts in the field. The following Prisma flow diagram summarises the process.



3. Discussion

This section presents the findings of the literature review. The first subsection explores the foundational concepts of transdisciplinary (TD) education. The second and third subsections examine the boundaries that TD education transcends, together with the key motivations driving its integration into higher education. The fourth subsection surveys the approaches and methods used

to implement TD education. The fifth subsection highlights some of the distinctive elements of the SciCulture & SciCultureD projects, offering a comparative perspective on their contribution to the broader landscape of TD education. The barriers to embedding transdisciplinary education are assessed in the final subsection.

3.1. Understanding Transdisciplinary Education

Transdisciplinary education is distinct from traditional learning processes since it involves a boundary-crossing approach that integrates diverse disciplines to address complex societal and scientific problems. Mulkey (2017) & Ma and Jin (2022) define transdisciplinary education as a methodology that integrates diverse disciplinary knowledge to solve complex societal and scientific problems, enabling students to "understand a broad range of disciplinary approaches, to ask creative questions, [and] to answer those questions with diverse tools." Similarly, Lopes et al. (2021) refer to it as an approach that merges multiple disciplines—Science, Technology, Engineering, Arts, and Mathematics (STEAM)— stressing how it connects "different subjects together in a way that they will relate to both the daily and professional world and to each other," which fosters critical thinking, creativity, and innovation.

Transdisciplinary education extends beyond integrating academic disciplines into stakeholder collaboration, breaking boundaries between academia and society. Baumber et al. (2022) highlight the collaboration with external stakeholders such as government agencies, industry partners, and community groups. Lorenz et al. (2022) stresses the need to engage diverse stakeholders to create actionable and socially relevant knowledge. Similarly, Lampoltshammer et al. (2021) argue that engaging external practitioners ensures students' learning outcomes are grounded in real-world sustainability challenges. Biberhofer and Rammel (2017) provide a concrete example through the Regional Centre of Expertise (RCE) Vienna, which fosters collaboration between academic institutions and communities to address societal needs through "joint problem definition and knowledge integration." Kovács and Talpoş (2015) highlight that "transdisciplinarity doesn't mean preserving distinctions but instead integrates them in a cognitive model and places them in relation to one another." This shows how cross-cultural interactions play a key role in transdisciplinary education.

Some authors elaborate on the philosophical underpinnings of transdisciplinary education. Gibbs (2017) argues that transdisciplinarity is a way of "being," emphasizing the "onto-epistemological approach to the world," which is a way of "seeing phenomena for what they are, not what can be made of them." He argues that this perspective shifts how individuals engage with complex problems, moving from passive observation to active understanding and transformation. McGregor (2017) highlights how transdisciplinary education integrates academic and societal "knowledge systems and lived experiences" to co-create innovative solutions to complex problems. She describes three core dimensions of transdisciplinary education (see Fig. 1 for an illustration of these dimensions): the learning process itself, characterized by the iterative transdisciplinary learning cycle (creative, descriptive, and normative phases), where participants engage in co-learning and boundary-crossing to develop shared understanding; the acquisition of transdisciplinary habits of mind, such as synthesizing, integrative thinking, and deep play, which prepare learners to navigate and merge diverse perspectives; and the collaborative generation of new transdisciplinary knowledge.

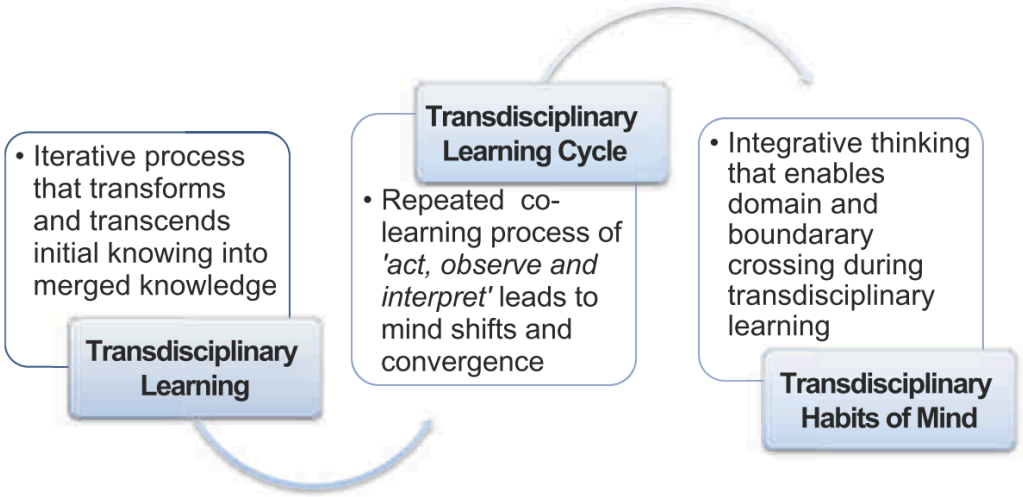


Fig. 1: Three dimensions of transdisciplinary learning (McGregor 2017)

This transformative character of transdisciplinary education is further highlighted by Sipos, Battisti, and Grimm (2008), who propose a holistic "Head, Hands, and Heart" model (see Fig. 2 for an illustration of this model) for Transformative Sustainability Learning (TSL). This model integrates learning processes across three domains: cognitive (head), involving intellectual engagement such as academic study and the development of an understanding of sustainability and global citizenship; psychomotor (hands), emphasizing the application of theoretical knowledge through practical skills and physical activities like building, painting, and planting; and affective (heart), focusing on enhancing values and attitudes that translate into behavior, such as cultivating a sense of community and taking responsibility both individually and collectively. For instance, planting a garden engages the psychomotor domain (hands), deepens cognitive understanding of ecological systems (head), and fosters emotional and social connections (heart), demonstrating the interconnectedness of these learning spheres. By synthesizing these domains, TSL enables learners to embody sustainability by linking knowledge, action, and values.

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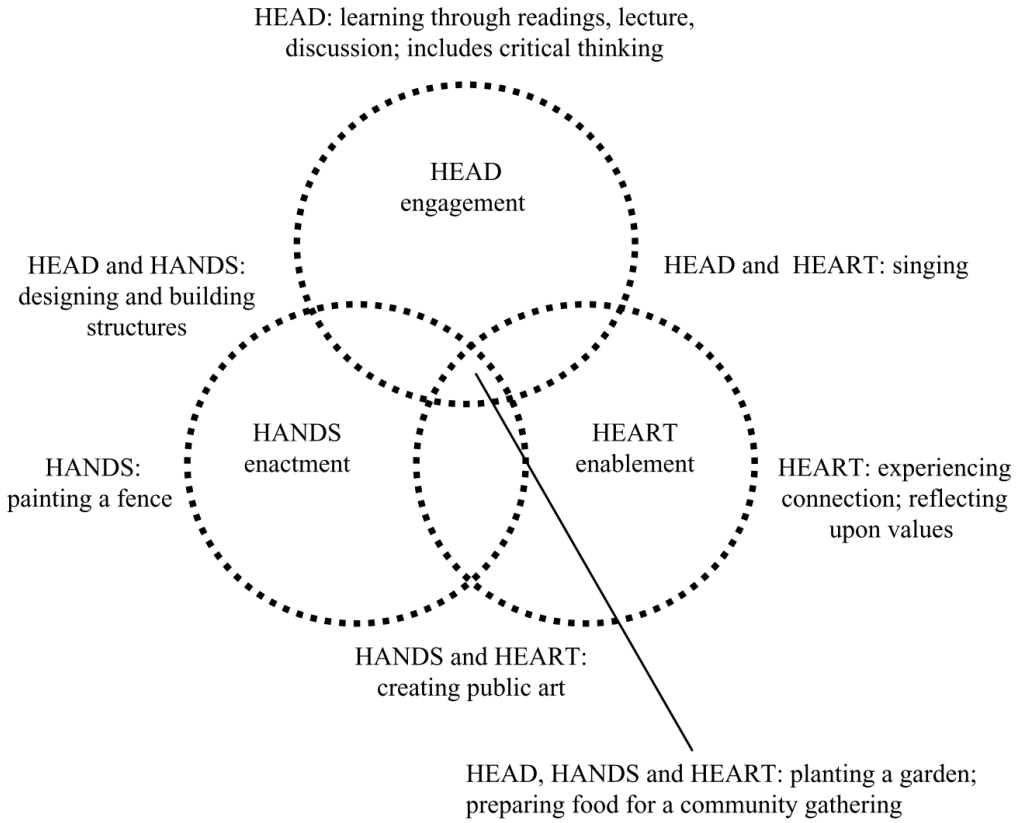

Fig.2: The *HEAD, HANDS, HEART* Principle for Transformative Sustainability Learning (TSL) (Sipos, Battisti, and Grimm 2008)

Transdisciplinary education bridges theoretical and applied knowledge through the incorporation of diverse disciplines, cultures and worldviews. Drawing on William C. Clark, Mulkey (2017) describes it as an enterprise of “use-inspired basic research” that integrates natural sciences, humanities, and social sciences within a liberal arts framework. Furthermore, Brogden et al. (2022) regard it as a “unified intellectual framework” fostering "a systems-scale mode of thinking".

By weaving together diverse disciplines, engaging stakeholders, and fostering philosophical and practical transformations, transdisciplinary education redefines learning by disrupting traditional ways of thinking and learning.

3.2. What Boundaries Are Typically Crossed in Transdisciplinary Education?

While the previous subsection showed that transdisciplinary education fundamentally involves crossing a range of boundaries—disciplinary, societal, cultural, and institutional, this subsection reveals what these boundaries look like.

Orozco-Messana et al. (2020) highlight how environmental sciences, engineering, architecture, and law can collaborate to foster practical, hands-on approaches to sustainability challenges in the built environment. Similarly, Baumber et al. (2022) describe the integration of natural sciences, social sciences, engineering, and creative arts, demonstrating how combining technical knowledge and external perspectives can address complex issues such as urban sustainability.

Frameworks like the TransDisciplinary Learning Community (TDLC) model, described by Lozoya-Santos et al. (2019), further emphasize how disciplinary boundaries are dismantled. They state that this model "brings together information, resources, data, theory, methods, and people from more than one discipline [...] encompassing the efforts of many over one real problem or necessity". This integrative approach eliminates "the boundaries of the disciplines through a process of strong collaboration". Other examples include the Science, Technology, Engineering, Arts, and Mathematics (STEAM) framework[3], which Ho and Pham (2022) describe as incorporating the arts into traditional STEM fields. They note that "STEAM brings together critical disciplines to create an inclusive learning environment that develops students' collaboration, communication, critical thinking and creativity skills." By combining technical and creative fields, STEAM exemplifies how transdisciplinary education bridges seemingly disparate fields.

Transdisciplinary (TD) education also crosses societal and institutional boundaries, creating bridges between academia and external actors such as communities, public agencies, and industries. McGregor (2017) articulates this clearly, describing transdisciplinary learning as a process that "transcends boundaries between higher education (mono, multi, and inter-discipline) and larger society (government, industry, citizens, and civil society)." By integrating academic and societal knowledge systems, Transdisciplinary education fosters the creation of "new TD knowledge, which is possible because boundaries have been broken down." Charli-Joseph et al. (2016) provide an example of this societal engagement by highlighting frameworks that involve NGOs, funding bodies, and public agencies. Similarly, Robinson et al. (2022) emphasize involving community stakeholders in transdisciplinary frameworks, enriching the learning experience and ensuring education is aligned with real-world needs. Lake et al. (2016) add to this by showcasing the value of community-based, participatory approaches in transdisciplinary education. These methods enable students to engage directly with local stakeholders, tackling "wicked" sustainability problems through hands-on learning and provide them with invaluable experience by bridging the gap between academic learning and real-world action.

Cultural and national boundaries are another significant frontier that is often crossed in TD education. Kovács and Talpoş (2015) argue that internet-based teamwork facilitates the crossing of cultural and disciplinary divides, allowing diverse perspectives to enhance integrated problem-solving. Such frameworks integrate global perspectives into the learning process, fostering innovation and adaptability. Saura-Mas et al. (2021) further note that TD education incorporates multidisciplinary and interdisciplinary perspectives into a macro-conceptual framework, which avoids being constrained by a single-discipline and instead allows for diverse intellectual inputs to shape solutions that consider all possible scenarios.

Integrative approaches in TD education culminate in the development of holistic curricula and innovative teaching strategies. Tasdemir and Gazo (2020) advocate for project-based learning (PBL) and hands-on activities that create "holistic, synergistic, balanced, and transdisciplinary" sustainability curricula. By breaking traditional academic barriers, such methods equip students with

[3] For a definition of the STEAM framework, see Chappell et al. (in press)

both technical knowledge and practical skills, fostering critical thinking and innovation. Gleason et al. (2021) support this view, noting that "leadership education is uniquely situated as a bridge between multiple disciplines and contexts" to empower students to tackle societal challenges systematically.

By crossing these boundaries, transdisciplinary education transforms how knowledge is created and applied. This new knowledge is highly required within certain circumstances and for certain reasons which will be explored in the next section.

3.3. The Underlying Rationale for Integrating Transdisciplinary Education in Higher Education Institutions

One of the core rationales for transdisciplinary education is its ability to enhance essential student skills. For instance, Kuzmenko et al. (2022) emphasize that integrating STEM approaches fosters "critical thinking, creativity, and skills of quick orientation and response in difficult situations". Similarly, Saura-Mas et al. (2021) claim that combining natural sciences, social sciences, and cultural disciplines equips students with a holistic understanding of complex realities, enabling them to engage critically with societal challenges. Moreover, Gleason et al. (2021) argue that transdisciplinary approaches empower students to address societal challenges creatively and systematically. In a similar vein, Lopes et al. (2021) note that STEAM education "aims to bring the 'real world' with its complexity into the classroom," fostering creativity, collaboration, and innovation.

Another motivation is the ability of transdisciplinary education to address complex societal and sustainability challenges. Orozco-Messana et al. (2020) argue that this approach fosters innovation and prepares students to tackle open-ended, real-world problems. Lake et al. (2016) reinforce this by noting that "educators can better prepare students to tackle such wicked problems by requiring they engage with locally based problems [such as food insecurity and urban farming] connected to large-scale systemic challenges". Molthan-Hill et al. (2019) highlight the role of transdisciplinarity in climate change education, emphasizing that universities can equip students with "climate change mitigation tools", preparing them to respond to ecological crises. Probst et al. (2019) echo this, arguing that transdisciplinary education enhances both "professional and personal skills as well as individual agency" to address "the wicked question of how to live sustainably". Similarly, Lozoya-Santos et al. (2019) highlight that transdisciplinary education fosters "the development of solutions to complex societal problems" by bridging "the existent gap between educational programs and the demands of the different sectors of the society, industry, and government."

In addition to that, transdisciplinary education enhances the societal relevance of higher education by collaborating with diverse stakeholders to achieve societal relevance. For instance, Charli-Joseph et al. (2016) emphasize its role in increasing the salience of sustainability education by making it relevant to societal needs, achieved through the engagement of external stakeholders such as NGOs and public agencies. Tercanli and Jongbloed (2022) show how Living Labs (LLs) are an excellent "interface for higher education institutions to collaborate with companies, citizens, non-profits, and government organizations." Dlouhá et al. (2012) further argue how what they call "the academic and multi-sector learning networks for education for sustainable development" help address complex sustainability challenges by fostering bottom-up, emergent processes of knowledge generations. These learning networks "reflect already existing practices of information exchange in society and apply/develop them within the learning process," enabling collaboration, social interaction, and shared learning goals among learners, institutions, and stakeholders.

Finally, transdisciplinary education supports holistic learning that integrates knowledge, skills, and values for transformative outcomes. Sipos, Battisti, and Grimm (2008) advocate for Transformative Sustainability Learning (TSL), which transforms participants' knowledge, skills, and attitudes by integrating "cognitive, psychomotor, and affective learning" empowering them to address ecological, social, and economic justice. Such holistic focus aligns with calls to re-envision education as a driver of systemic change.

Transdisciplinary education is a response to the increasing complexity of our world. Emerging societal challenges demand not only sophisticated skills but also collaborative frameworks that engage diverse stakeholders and empower students to drive systemic change. However, realizing these conditions requires strategies and frameworks that effectively embed transdisciplinary education within higher education institutions. The following section explores the diverse methods and approaches employed to integrate transdisciplinary education into curricula and institutional practices.

3.4. Embedding Transdisciplinary Education: Diverse Approaches and Strategies

Embedding transdisciplinary (TD) education within higher education institutions requires innovative pedagogical frameworks that foster collaboration, problem-solving, and engagement with real-world challenges. The following approaches, drawn from diverse literature, illustrate how curricula can effectively promote TD learning across academic and societal contexts.

One of the widely recognized methods for fostering transdisciplinary (TD) education is Problem- and Project-Based Learning (PBL/PjBL). Orozco-Messana et al. (2020) highlight Problem-Based Learning (PBL) as central to TD education, integrating technical competencies with teamwork and sustainability concepts. In their programme, students addressed open-ended challenges such as carbon capture, green infrastructure and integrated design in teams of 3–4, combining diverse academic and cultural backgrounds. Daily presentations by faculty provided foundational knowledge, while social interactions and collaborative activities enhanced creativity and innovation. Inspired by the "bandstand" jazz metaphor, this model (see Fig. 3 for an illustration of this model) emphasized improvisation and fluidity, where students built upon each other's ideas, and developed practical and analytical skills.

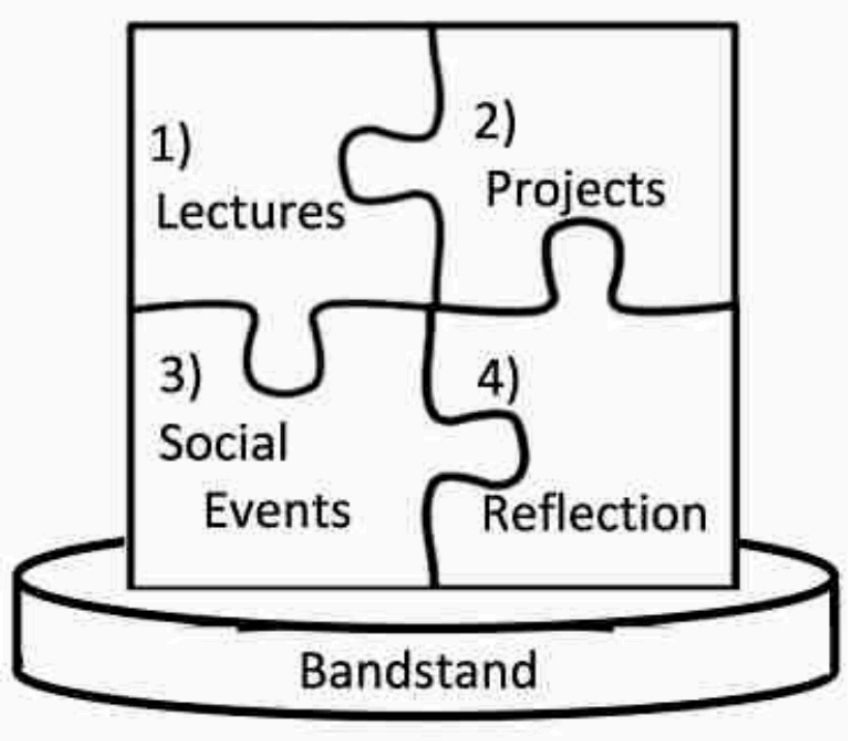

Fig. 3: The elements of a bandstand workshop (Orozco-Messana, La Poza-Plaza, and Calabuig-Moreno 2020)

Similarly, Charli-Joseph et al. (2016) implemented PBL as a core component of their transdisciplinary framework. Their curriculum development process incorporated a backward design approach[4], aligning learning outcomes with sustainability challenges. Participatory workshops and stakeholder engagement ensured societal relevance and built trust, while students worked on defining and solving real-world sustainability problems. Participatory approaches are taken to a different level by Similarly, Bosman et al. (2019) employ participatory research methods, such as photovoice and focus groups, to actively involve students in shaping transdisciplinary education programmes. In this approach, "students act as researchers", contributing to data collection and analysis to identify challenges and propose solutions for curriculum development. Tasdemir and Gazo (2020) extend the traditional lecture-based teaching, by incorporating project-based learning (see Fig. 4 for an illustration of their approach) and modern management techniques, such as Lean Manufacturing, Six Sigma, and Life Cycle Analysis. This pedagogical approach emphasizes critical thinking, hands-on learning, and real-world applications to promote innovative and sustainable design solutions.

[4] Backward design approach is used to define "the programme learning outcomes (PLOs)," which are "statements describing what students can reliably demonstrate at the end of the programme and key competencies." (Charli-Joseph et al. 2016, p383.)

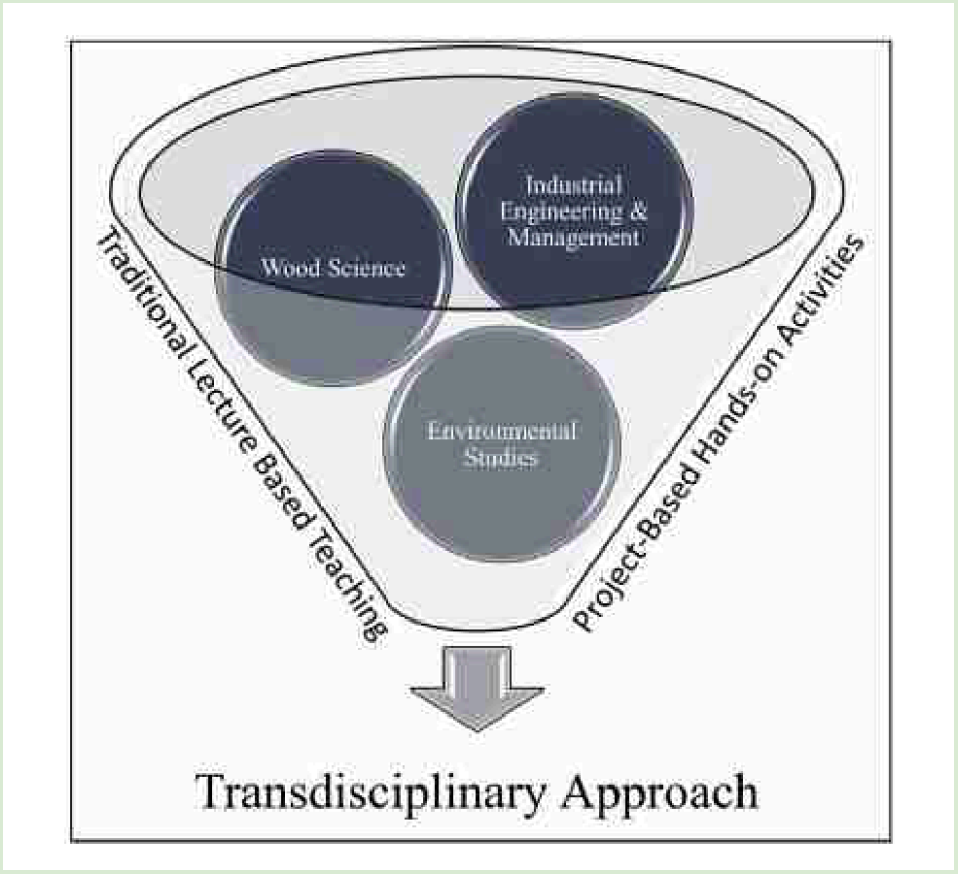

Fig.4: Illustration of transdisciplinary nature of course design (Tasdemir and Gazo 2020)

Collaborative, experiential learning plays a crucial role in transdisciplinary education, fostering real-world engagement and problem-solving. Meyer et al. (2017) describe how they brought together university educators, researchers, and stakeholders to address sustainability challenges in Albania and Kosovo as part of the ConSus project. By engaging stakeholders such as NGOs, businesses, and regional agencies, participants co-developed solutions to real-world socio-ecological issues, fostering knowledge exchange and capacity building. Similarly, Lake et al. (2016) employ community-based participatory learning and iterative processes of problem-framing, reframing and revision to address wicked sustainability challenges. Through reflective practices like mind mapping, students develop skills such as epistemic humility, creative confidence, and open-minded advocacy, empowering them to co-create solutions with local stakeholders. Brogden et al. (2022) expand on collaborative, experiential learning by incorporating action learning, live projects and group work to strengthen community resilience. Lorenz et al. (2022) highlight Real-World Laboratory “Ackerbaum,”which combines interdisciplinary collaboration, field-based research, and practical engagement with local stakeholders, including farmers and non-academic practitioners. Students are involved in tasks such as designing agroforestry systems, implementing experimental setups, and conducting data collection and analysis. Probst et al. (2019) extend this by focusing on transformative learning through real-world discourse and dialogue. Their approach emphasizes collaborative problem-solving and

integrative thinking in sustainability education, preparing students to critically assess systems such as agri-food systems.

Innovative pedagogies such as the macro-concept and polyhedral systems are introduced by Saura-Mas et al. (2021). The macro-concept, which refers to “the integration of order, disorder, interaction, and organization,” transcends disciplinary boundaries, allowing students to holistically explore real-world issues. The polyhedral systems approach enables students to construct “constellations of concepts” around the macro-concept, which allows “all the possible scenarios instead of being kidnapped by a concrete discipline,” encouraging critical thinking and a deeper understanding of sustainability challenges.

Other unique approaches include the establishment of TransDisciplinary Learning Communities (TDLC) as described by Lozoya-Santos et al. (2019), where academic knowledge and practical challenges are bridged by involving students, faculty, and external stakeholders in joint problem-solving. They state that TDLCs “strengthen and complement HEI educational programs, as students participate in transcendental learning environments finding solutions to real problems, in collaboration with colleagues from other subject areas, from other universities, and in close cooperation with small, medium and big enterprises and governmental agencies.”

Challenge-based and action-oriented learning remains a core approach for embedding TD education. Baumber et al. (2022) describe how students are engaged in activities such as “mapping out the various stakeholders and elements within the system using simple system maps, influence diagrams, causal loops, rich pictures, agent-based modelling and stocks and flows models." Strategies "such as adaptive management and safe-to-fail experiments” enabled students to co-design interventions addressing complex societal challenges. Similarly, Carrapatoso (2021) provides concrete examples where students co-designed sustainability initiatives with local stakeholders, including a GPS-based city tour on sustainability, developed in cooperation with teachers and tested with school classes. By applying theoretical knowledge to practical scenarios, students cultivated project management, teamwork, and problem-solving. This shows how action-oriented approaches provide students with the tools to bring “knowledge about sustainable development into action” while experiencing “all highs and lows” of project implementation. The central role of design thinking (DT) in fostering creativity, empathy, and action-oriented learning is further emphasized by Lake et al. (2022). They describe DT as an "iterative, project-based and collaborative problem-solving process" where students use methods such as empathy-focused interviews, brainstorming, and prototyping to collaborate with local stakeholders in co-creating, for example, a "wellness-themed fence painted by the community" or designing a "healthy food kit for after-school programs."

Community-based learning also features prominently in the literature under consideration. Mahlangu and Garutsa (2019) explore the transformative potential of transdisciplinary approaches by integrating indigenous knowledge (IK) and community-based learning into higher education curricula. They discuss the use of dialogical and collaborative pedagogical methods, such as group work and problem-solving projects that engage students with real-life societal challenges. For example, the Life Knowledge Action/Grounding Programme at the University of Fort Hare requires students to conduct community-based research, reflect on local issues such as HIV/AIDS, climate change, and socio-economic problems, and propose solutions, which foster deeper social engagement and cross-cultural learning.

Sipos, Battisti, and Grimm (2008) draw on the so-called “transformative pedagogies” in introducing Transformative Sustainability Learning (TSL), a model that involves “action learning, community

service-learning, critical emancipatory pedagogy, environmental education, participatory action research, pedagogy for eco-justice and community, problem-based learning, and traditional ecological knowledge." By integrating learning processes across three distinct areas of engagement: heads-on (cognitive), hands-on (psychomotor), and hearts-on (affective), TSL fosters values and attitudes that translate into behavior, such as cultivating a sense of community. A key example is the UBC farm courses, where students participated in sustainability projects focused on "global citizenship, agroecology, food systems and local economic systems."

Some literature emphasize the need to integrate leadership and governance within transdisciplinary education to increase social relevance and empower students. Kiravu et al. (2018) highlight the importance of policy integration and participatory processes, in equipping students to understand and address challenges at the political, economic, and societal levels. Similarly, Gosselin et al. (2016) argue that addressing wicked problems necessitates leadership and collaboration. Furthermore, Gleason et al. (2021) highlight the importance to integrate leadership studies and community collaboration, with the aim to produce holistic solutions for complex societal challenges.

Technology and digital environments also play a pivotal role in transdisciplinary education. Dlouhá et al. (2012) advocate for learning networks which incorporate bottom-up processes, Information and Communication Technology (ICT)-supported environments, and collaborative, case-based learning to promote active participation, knowledge co-creation, and boundary-crossing interactions. One example is the Virtual Campus for Sustainable Europe (VCSE) which supports intercultural teamwork through e-learning. Moreover, Lampoltshammer et al. (2021) propose a teaching framework for digital sustainability that fosters flexibility, accessibility, and inclusivity, especially for postgraduate students addressing sustainability challenges. By anchoring student work in real-world challenges and promoting interaction with practitioners, the framework ensures the development of digital competencies needed to address sustainability issues effectively.

Lopes et al. (2021) highlight the importance of integrating the arts in transdisciplinary education as part of their exploratory project on STEAM for Higher Education, emphasizing that "art is a process of inquiry and a way of knowing" that fosters collaboration across disciplines. They argue that arts permeate society and "serve to instill forums for questioning, redefining, and offering new visions of the relationship between science/technology and society." In their experimental STEAM settings, "creation is not dissociated from subjectivity and human ways of being," allowing participants to negotiate complex ideas shaped by "situated knowledge, social interactions, human ideologies, cultures, systems, and structures of power." By promoting hybrid labs, interdisciplinary workshops, and hackathon-style activities, Lopes et al. stress the need for academia to "embrace non-formal learning strategies and partnerships" to produce new transdisciplinary knowledge and foster "empathic qualities towards society, economy, and politics."

The approaches outlined demonstrate the breadth of strategies for embedding transdisciplinary (TD) education, reflecting a shift away from traditional educational paradigms. In the next section, we examine how SciCultureD compares to other TD education models discussed in the literature.

3.5. SciCulture's Approach to Transdisciplinary Education: A Comparative Perspective

The SciCulture (and its subsequent version SciCultureD) project, as analysed in Chappell et al. (2023), both aligns with and diverges from the broader understanding of transdisciplinary education discussed above in the literature. While there is a shared emphasis on creativity, interdisciplinarity,

and societal engagement as foundational aspects of transdisciplinary education, the SciCulture project introduces a distinctive posthuman and materialist perspective, expanding beyond the approaches typically found in the broader literature.

In defining transdisciplinary education, sources like Baumber et al. (2022) and Brogden et al. (2022) emphasize the integration of diverse academic fields alongside collaboration with non-academic stakeholders to address complex societal issues. Chappell et al. (2023b) similarly situate higher education within an immersive, transdisciplinary framework that merges arts, sciences, and entrepreneurship. However, they push this concept further by incorporating methodologies that emphasize materiality, spatiality, and posthuman creativity. They stress how "new ideas are generated through materially embodied dialogic interactions between many different kinds of 'voices'...with subjectivities generated through the very process of intra-action." This distinctive approach challenges Western onto-epistemological frameworks and contrasts with the more human-centric and discipline-focused methods commonly found in traditional higher education.

As a response to the limitations of Western-centric frameworks in transdisciplinary education, Chappell et al. (2023) propose to integrate indigenous knowledge systems and non-Western approaches as crucial for achieving genuinely transformative transdisciplinary education. They argue that to move beyond conventional disciplinary boundaries, it is essential to embed principles of ethics, social justice, and care for future generations within the learning process. This perspective intersects with some of the literature focusing on sustainability and social justice (e.g., Sipos, Battisti, and Grimm 2008; Probst et al. 2019; Tercanli and Jongbloed 2022) ; however, Chappell et al.'s emphasis on decentering the human and incorporating materiality as a co-creator of knowledge presents a novel and expanded view of transdisciplinary education.

In terms of the rationale for embedding transdisciplinary education, many articles (e.g., Molthan-Hill et al. 2019; Orozco-Messana, La Poza-Plaza, and Calabuig-Moreno 2020; Probst et al. 2019; Lozoya-Santos et al. 2019) highlight the importance of collaborative, interdisciplinary strategies for addressing global challenges such as climate change and urban sustainability. Chappell et al. (2023) build on these ideas by integrating design thinking and creative pedagogies to reimagine higher education institution (HEI) practices in ways that prioritize ethicality and social justice. By emphasizing the centrality of materiality and spatiality, they suggest that educators and students can create learning environments that respond to ecological and societal crises. This approach goes beyond the traditional ecological or policy-oriented frameworks highlighted in other sources, advocating for an intra-active engagement where human and non-human elements co-create knowledge.

Regarding approaches to embedding transdisciplinary education, the broader literature frequently references immersive methods like project-based learning (e.g., Orozco-Messana, La Poza-Plaza, and Calabuig-Moreno 2020; Tasdemir and Gazo 2020) community-based research (e.g., Mahlangu and Garutsa 2019; Lake, Fernando, and Eardley 2016). The SciCulture project aligns with these methods but introduces the dimension of posthumanist creativity, where learning is framed as an emergent, iterative process shaped by material and spatial interactions. For instance, Chappell et al. (2023) illustrate the use of art, film, and interactive digital tools to engage participants in transdisciplinary

learning experiences that extend beyond conventional classroom settings. This fusion of traditional and innovative methods offers a distinct approach.

Similarly to creative pedagogies, as described by Chappell et al. (2023) and implemented in SciCulture(-D), transformative pedagogies, as outlined by Sipos, Battisti, and Grimm (2008) integrate arts to foster transdisciplinary learning. However, employing arts in transformative pedagogies is instrumental, serving as a means to achieve behavioural transformation by integrating cognitive (head), psychomotor (hands), and affective (heart) domains. In contrast, in creative pedagogies, arts are not merely tools but fundamental elements of provoking relational and innovative responses to wicked problems. This is in line with Lopes et al. (2021) view on the roles arts should play in "offering new visions" and enabling socially "empathic" innovation. Yet creative pedagogies go further by de-centring human perspectives and incorporating materiality, spatiality, and relationality as essential to reimagining education and addressing complex societal challenges.

In summary, while there is considerable overlap between the SciCulture(-D) project and broader perspectives on transdisciplinary education—particularly in the emphasis on interdisciplinarity and societal impact—Chappell et al. (2023) make a unique contribution by framing transdisciplinary education through a posthuman and materialist lens. This approach seeks not only to address complex problems but also to transform the epistemological and methodological foundations of higher education, advocating a shift from traditional Western paradigms toward more inclusive, ethical, and future-focused practices.

3.6. Scope and Challenges of Embedding Transdisciplinary Education in Higher Education Institutions

Embedding transdisciplinary education (TD) in higher education institutions (HEIs) presents a wide array of opportunities but is accompanied by substantial challenges. Many HEIs recognize the transformative potential of TD approaches, especially in addressing complex global issues like sustainability and climate change. Orozco-Messana et al. (2020) exemplify this by detailing student-led programmes co-designed with external stakeholders to develop sustainability solutions. Such initiatives not only enhance academic learning but also ensure that students' work has real-world relevance, reinforcing the role of transdisciplinary education in fostering practical, collaborative problem-solving.

Despite these benefits, TD education often remains confined to specialized departments or centres. Baumber et al. (2022) and Molthan-Hill et al. (2019) highlight the prevalence of TD programmes within environmental science or sustainability hubs, demonstrating that while significant, transdisciplinary education is still frequently siloed within specific areas rather than widely adopted across HEIs. Molthan-Hill et al. (2019) outline a progressive model for integration—ranging from Piggybacking (adding transdisciplinary elements to existing courses) to Mainstreaming, Specializing and Connecting (developing fully integrated, cross-disciplinary curricula). Both Baumber et al. (2022) and Molthan-Hill et al. (2019) highlight the demand for institutional and systemic restructuring, significant staff time, and resource allocation, as well as careful planning and management of various aspects of the process. Similarly, Lake et al. (2022) highlight systemic issues such as limited time, resources, and siloed policies within HEIs that hinder collaboration across departments and with

external partners. As a result, implementing transdisciplinary education in HEIs is only possible through a gradual and often challenging process.

Cultural and institutional resistance further complicates the integration of transdisciplinary education. Mahlangu and Garutsa (2019) identify entrenched disciplinary silos, marginalization of indigenous knowledge (IK), and tensions between Western and non-Western epistemologies as persistent barriers. Integrating diverse knowledge systems requires overcoming deep-rooted hierarchies within academia and fostering trust among collaborators. McGregor (2017) stresses the importance of navigating disciplinary jargon, aligning values, and building mutual respect to facilitate effective partnerships across- and beyond disciplines. Lopes et al. (2021) add that rigid institutional frameworks and adherence to conventional rules often discourage innovation, with many perceiving structural change as unattainable. Nevertheless, they argue that fostering creativity and institutional flexibility can mitigate these challenges, enabling the gradual transformation of academic curricula.

Challenges also manifest at the student level. Guo et al. (2020) note the time-intensive nature of project-based learning (PjBL), a cornerstone of many TD programmes, as a significant obstacle. Students frequently struggle to balance demanding project work with other academic responsibilities. Additionally, group dynamics—such as unequal task distribution, communication barriers, and interdisciplinary collaboration—can impede progress, necessitating clearer guidelines and robust faculty support to ensure equitable participation and knowledge integration. Lake et al. (2022) further stress that semester timelines, a “lack of long-term multistakeholder support and learning networks”, and the emotional load of immersive, high-stakes learning environments can further exacerbate these difficulties, leading to burnout and low morale among participants. Another critical barrier to embedding transdisciplinary (TD) education lies in balancing student-driven learning with cohesive programme outcomes. Bosman et al. (2019) underscore the difficulty of creating flexible yet structured TD programmes that address diverse student needs while aligning with professional competencies.

Funding constraints present another hurdle. Tercanli and Jongbloed (2022) emphasize the pivotal role of EU-funded projects (e.g., Horizon 2020, Interreg) in sustaining Living Labs and other TD initiatives within European HEIs. While such programmes provide vital financial support, reliance on external grants can limit scalability and long-term sustainability, reinforcing the need for HEIs to secure diverse funding streams and internal commitment to transdisciplinary education. Charli-Joseph et al. (2016) similarly point to philanthropic organizations as key enablers of TD curricula, particularly in sustainability and climate action fields. However, unbalanced and preferential funding can restrict the expansion of transdisciplinary initiatives beyond a few academic programmes.

In summary, while the integration of transdisciplinary education offers immense potential for addressing complex societal issues, its widespread adoption across HEIs is often impeded by structural, financial, and cultural barriers. Addressing these challenges requires incremental, well-supported strategies that emphasize collaboration, inclusivity, and institutional innovation, paving the way for transdisciplinary education to become a cornerstone of future academic practice.

Conclusion

The literature reviewed highlights the transformative potential of transdisciplinary (TD) education in reshaping higher education to address complex societal and environmental challenges. By integrating diverse disciplinary perspectives and fostering collaboration with external stakeholders, TD education transcends traditional academic boundaries, equipping students with the skills and mindset needed to tackle "wicked" problems. Central to this approach is the blending of theory and practice, fostering innovation, creativity, and a holistic understanding of global issues.

However, the review also underscores significant challenges in embedding transdisciplinary frameworks within higher education institutions (HEIs). Structural barriers, disciplinary silos, and limited institutional resources often hinder the widespread adoption of TD education. Additionally, cultural resistance, rigid curricula, and the dominance of Western epistemologies present further obstacles to creating inclusive and socially responsive TD programmes. Despite these challenges, successful models such as problem-based learning (PBL), community-based initiatives, and immersive, participatory projects illustrate the potential for transformative educational experiences.

The SciCulture and SciCultureD projects offer valuable insights into the evolving landscape of TD education, introducing posthuman and materialist perspectives that extend beyond traditional frameworks. Their emphasis on creativity, relationality, and stakeholder co-creation presents a forward-looking model for higher education.

In conclusion, while transdisciplinary education holds significant promise for fostering innovation and addressing pressing global issues, its effective implementation requires institutional flexibility, collaborative leadership, and sustained investment in both pedagogy and infrastructure. The ongoing evolution of TD education will depend on the capacity of HEIs to adapt, innovate, and engage with broader societal needs.

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