Art-Based Teaching in Sustainability Higher Education:

Benefits, Challenges, and Competency Development

M.Sc. Industrial Ecology

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Summary

Education plays a central role in enabling sustainable societies, as highlighted by the emergence of Education for Sustainable Development (ESD) following the 1992 UN Conference on Environment and Development. Within higher education, sustainability-focused programs, referred to in this study as sustainability higher education (SHE), aim to equip students with key competencies needed to address complex sustainability challenges, often requiring transformative and interdisciplinary pedagogical approaches. In this context, art-based teaching (ABT) has gained attention as a method that can enhance learning by encouraging creativity, critical thinking, emotional processing, and collaboration, while addressing diverse sustainability topics. Industrial Ecology (IE) programs provide a pertinent case study for exploring ABT integration, given their interdisciplinary approach to complex environmental challenges and the current lack of research on ABT in this domain. Despite growing interest, knowledge gaps remain regarding the contextual factors influencing ABT integration, its benefits and challenges, and how these practices contribute to sustainability key competencies. This study addresses these gaps by combining through a systematic literature review of 11 peer-reviewed articles on SHE and 14 interviews with educators and students from four Northern European IE programs, aiming to provide educators with evidence to support the transformative potential of ABT in sustainability higher education.

The study first investigated how and why ABT practices are incorporated in SHE. Analysis revealed a wide range of practices across disciplines, highlighting the influence of contextual factors such as group size, teaching team expertise, and co-teaching with artists. Active student participation was common and enhanced engagement and ownership, while non-participatory approaches also provided value. Purposes of ABT interventions such as mapping systems, expressing emotions, and generating ideas, aligned with literature on higher education goals while reflecting research-oriented objectives, particularly from the empirical data in IE.

The study then identified 26 potential benefits and 15 challenges of ABT integration. Benefits demonstrated the broad potential of ABT for sustainability education, whereas challenges highlighted pedagogical and implementation barriers and raised questions about cultural and educational paradigms in Western higher education.

Linking these benefits to the Brundiers et al. (2021) sustainability key competencies framework confirmed trends observed by Heras (2022): ABT particularly supports intrapersonal, interpersonal, and normative competencies. Additionally, this study highlighted the potential for ABT to contribute to futures-thinking and systems-thinking competencies, especially as reported by educators in IE. No clear evidence was found regarding the contribution of ABT to implementation competencies.

Future research could broaden the scope by including participants from diverse disciplinary, cultural, and educational contexts, particularly non-Western or Indigenous traditions where art is central to knowledge transmission. Long-term impacts of ABT on student engagement, behavior, and professional practice should be investigated, along with institutional factors such as curriculum design, assessment systems, and educator training that could support the integration of art in higher education.

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List of abbreviations

ABT	Art-Based Teaching
CCE	Climate Change Education
EE	Environmental Education
ESD	Education for Sustainable Development
ESE	Environmental and Sustainability Education
HEfSD	Higher Education for Sustainable Development
HEI	Higher Education Institution
IE	Industrial Ecology
KTH	Kungliga Tekniska högskolan
NTNU	Norges Teknisk-Naturvitenskapelige Universitet
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SDG	Sustainable Development Goal
SHE	Sustainability Higher Education
SRQ	Sub-Research Question
UNESCO	United Nations Educational, Scientific and Cultural Organisation

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Chapter 1. Introduction

1.1. Teaching sustainability

In the face of climate change and its impacts on populations and biodiversity, education was identified as having a central role in transitioning to sustainable societies. This was formally acknowledged during the 1992 United Nations Conference on Environment and Development (Buckler & Creech, 2014). From that conference, Education for Sustainable Development (ESD) emerged as a global initiative to encourage actors, on all educational levels and spheres, to promote sustainability teachings (Weiss & Barth, 2019; Buckler & Creech, 2014).

To better explore how ESD can be implemented at different educational levels, the term Higher Education for Sustainable Development (HEfSD) emerged in the scientific literature. In this context, Higher Education Institutions (HEIs) promote HEfSD by addressing sustainability issues on campus, by supporting the development of sustainability-focused programs, and therefore by encouraging behavioural change amongst staff, students, and the wider community (Leal Filho et al., 2021; Franco et al., 2019; Buckler & Creech, 2014). Indeed, the past decades have seen the proliferation of sustainability programs in higher education globally (Wiek et al., 2011; Weiss & Barth, 2019). For the current study, the term sustainability higher education (SHE) will be used to emphasise the study's focus on higher education programs teaching sustainability and environmental education.

As these sustainability programs continue to grow, researchers have sought to better understand what kinds of skills and learning outcomes they should aim to promote. As a result, a large body of scientific literature attempted to define and build a framework for sustainability key competencies (Wiek et al., 2011; Rieckmann, 2012; Brundiers et al., 2021; Redman & Wiek, 2021; Rieckmann, 2018). The aim of sustainability key competencies is to equip individuals with the knowledge, skills, values, and attitudes needed to address complex sustainability challenges and contribute to a more sustainable future (Redman & Wiek, 2021). With sustainability challenges affecting many disciplinary areas of study, it is with inter- and transdisciplinary approaches that they may be analysed and understood. To support the achievement of these competencies, pedagogical strategies that go beyond traditional disciplinary boundaries are required (Wiek et al.,

2011; Molderez & Ceulemans, 2018). It is also argued that the challenges presented by unsustainability call for the rethinking of educational approaches and pedagogy in higher education, referred to as transformative, or even transgressive, learning (Lotz-Sisitka et al., 2015; Scarff Seatter & Ceulemans, 2017). Transformative learning encourages learners to think critically and creatively to come up with their interpretations of the world, and aims to "produce major changes in thinking, feeling, acting, relating, and being" of students (Scarff Seatter & Ceulemans, 2017, p. 56; Bennetts, 2003). In response to this call for transformative approaches to sustainability education, educators and researchers have increasingly explored alternative methods to enrich learning experiences and support these sustainability key competencies (Heras, 2022; Molderez & Ceulemans, 2018). This gave rise to approaches such as place-based learning or problem-based learning that offer alternative ways for students to analyse sustainability issues, more rooted in community interactions and real-world challenges (Brundiers et al., 2010).

Additionally, there has been a growing interest in approaches that integrate arts and sustainability education (Heinrichs, 2021; Heras et al., 2021; Papavasileiou et al., 2020). Across educational levels and spheres, studies have reported that using art-based teaching (ABT) for ESD is beneficial for students in many ways. In the classroom, art can help students make abstract concepts more concrete, enhance group collaboration, and stimulate imagination to come up with new solutions for sustainability challenges (Heras et al., 2021; Molderez & Ceulemans, 2018; Wall et al., 2019). On an individual level, art can help in expressing and processing (negative) emotions related to climate change, which many students are faced with (George, 2024; Wardle, 2025). Art has been introduced in ESD to address many (un)sustainability topics, including climate change, ecosystems and biodiversity loss, indigenous knowledge, environmental rights, and connection with nature (Heras, 2022). Overall, the use of art practices for sustainability education aligns with the field's need for non-traditional approaches, by aiming at bringing about transformative change not solely through content but also through the methods it applies (Heras et al., 2021).

1.2. Industrial Ecology as a case study

Higher education programmes teaching the methods and contents of Industrial Ecology (IE) are an example of sustainability-focused programs. IE, as a field, attempts to tackle the 'wicked problems' of sustainability by analysing the flows of materials and energy through industrial systems using interdisciplinary approaches to sustainable resource management (IESE, 2025;

Rittel & Webber, 1973). By integrating circular economy principles to minimise environmental impact and enhance social and economic well-being, IE addresses major sustainability challenges such as climate change, pollution, and resource depletion (Bringezu, 2017). As demonstrated by the numerous educational programs spanning different levels of study (i.e., undergraduate, graduate, and doctoral) and different countries (e.g., China, France, Germany, Netherlands, Sweden, Norway, Belarus, Thailand), IE has become a specific study domain in post-secondary education (Finlayson et al., 2014). Little research has been done specifically looking at the integration of art in the IE domain. Eckelman & Laboy (2020) have looked at how art can be used as a way to display results from a life cycle assessment (LCA), which thus focuses on the integration of art in research processes. However, to the author's knowledge, no study looked at the use of ABT in IE higher education programs. Therefore, IE higher education programs offer a case through which to examine which ABT methods are being applied in practice, how they are being applied, and how these might contribute to sustainability key competencies. This study takes IE as a case study to explore how such approaches are implemented, and what challenges and opportunities arise in doing so.

1.3. Research gap and aims

Current educational approaches in SHE often rely on traditional methods, which may not completely address the affective and sensorial dimensions of learning (Delahaye et al., 2020). First, while there is a body of literature on HEfSD exploring how ABT can be applied in practice, there is still a lack of overview concerning the contextual factors and the characteristics of their integration in sustainability education. Having an overview of the contextual factors can show the diversity or common trends of practices and contexts in which ABT is integrated. Second, there is also no review of ABT practices' benefits and challenges in SHE broadly, nor in IE specifically, as a more engineering and technical-oriented sustainability field. Providing an overview of the benefits and challenges of the integration of ABT in SHE and IE programs can support the implementation of these practices whilst informing on the particular challenges that might hinder their uptake by HEIs. Third, very few studies exploring the use of ABT methods in sustainability higher education analyse how the benefits of these approaches can help achieve sustainability key competencies. Analysing the contribution of ABT practices to key competencies in sustainability

can provide a stronger argumentation for the integration of such methods in sustainability programs curricula.

This study addresses these gaps by exploring the contextual factors, benefits and challenges of ABT in SHE through a systematic review of the literature, and identifies these same aspects empirically using IE programs as a case study. Contributions of ABT practices to sustainability key competencies are then analysed based on the benefits recorded from the implementation of ABT in both SHE and in IE programs. A summary of the research gaps and aims is displayed in **Figure 1.3**. By bridging these gaps, this exploratory study's overall aim is to equip educators and sustainability education staff with supporting evidence for the integration of ABT methods as transformative approaches to tackle sustainability challenges.

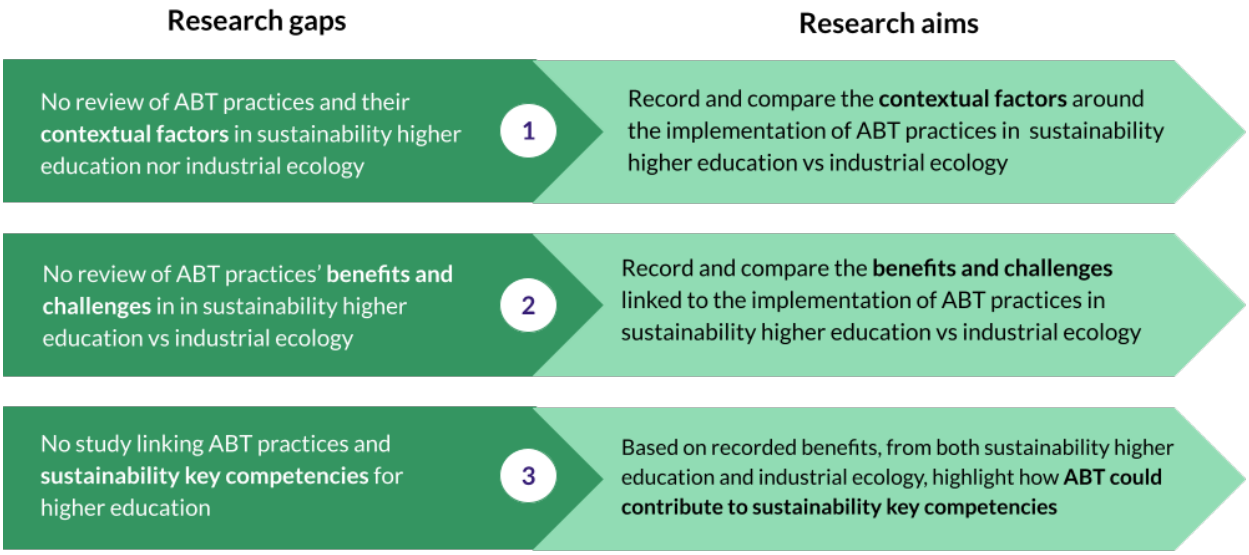

Figure 1.3. Overview of research gaps addressed by this study, and consequent research aims.

1.3. Research questions

The main research question of this thesis is: **"What are the benefits and challenges of integrating art-based teaching in sustainability higher education to support the achievement of key competencies?"**

Four sub-research questions have been developed to further structure this research:

SRQ1. How and why has art been used in SHE?

SRQ2. What are the reported potential benefits of including art practices for SHE?

SRQ3. What are the reported potential challenges of including art practices for SHE?

SQR4. Which sustainability key competencies could be achieved through ABT based on the benefits reported from SHE?

1.4. Thesis outline

Following this chapter, Chapter 2 will provide the conceptual frameworks and background information on the integration of ABT practices in SHE, on the development of frameworks of sustainability key competencies, and on the current reported integration role of art in IE. Chapter 3 will introduce the research methods used to answer the sub-research questions. Chapter 4 presents the findings from the data collection and analyses, followed by a discussion in Chapter 5 comparing the outcomes obtained from broader SHE data to outcomes empirically collected from IE educators and students. Finally, Chapter 6 concludes this study by summarising the discussion points and providing avenues for future research.

Chapter 2. Literature review and theoretical background

2.1. Nomenclature on sustainability education

In the literature, several overlapping terms are used to describe education that addresses environmental and sustainability issues. This section summarises the most commonly used terms in the literature and gives an overview of the different strands of educational traditions that aim at promoting sustainability education. Environmental education (EE) is one of the oldest terms, emerging in the 1970s and formally defined by UNESCO in the Tbilisi Declaration (1977) (Hume & Barry, 2015; Nazir et al., 2009). It arose in reaction to environmental problems caused by industrialisation and rising consumerism and focused on increasing awareness and understanding of the environment and promoting responsible behavior (Hume & Barry, 2015). Education for Sustainable Development (ESD) was introduced as a global initiative during the 1992 United Nations Conference on Environment and Development (UNCED) and later formalised in international frameworks such as the Decade of ESD (2005–2014) and the UN Sustainable Development Goals (particularly SDG 4.7) (Buckler & Creech, 2014; United Nations, 2025). It aims to promote critical thinking and action around environmental, social, and economic sustainability. Climate change education (CCE) is a more recent term that gained traction in response to the urgency of climate issues, particularly after the Paris Agreement (2015), and is promoted by UNESCO and other agencies as part of ESD (Molthan-Hill et al., 2021; Monroe et al., 2019). It focuses specifically on understanding climate science, impacts, and mitigation or adaptation strategies. Finally, environmental and sustainability education (ESE) is often used in academic literature as a broader term that encompasses many of the terms described above (University of Toronto, 2024). In this thesis, the term SHE is used and refers to university-level programs that address sustainability and environmental challenges, regardless of the exact terminology used in each program or study.

2.2. Key competencies in sustainability education

Sustainability higher education programs are designed to equip students with the knowledge, skills, values, and competencies needed to contribute to sustainable development, often through interdisciplinary or transdisciplinary approaches (Brundiers et al., 2021). They may be offered as dedicated sustainability degrees (e.g., Sustainability Science, Environmental Studies) or embedded within broader fields (e.g., engineering, business, education) that incorporate sustainability as a core dimension. Wiek et al. (2011) present a review of the literature to define key competencies considered central for sustainability education. The review identifies literature on key competencies in sustainability and synthesises contributions into a framework of sustainability research and problem-solving competence. The study's aim is institutional advancements in designing and revising academic programs, teaching and learning evaluations, and hiring and training faculty staff. The authors define a competence as a functionally linked complex of knowledge, skills, and attitudes that enable successful task performance and problem-solving. Key competencies are differentiated from regular competencies and are considered essential for sustainability, requiring special attention. The study identifies five key competencies: systems-thinking, anticipatory, normative, strategic, and interpersonal.

Brundiers et al. (2021) built upon Wiek et al.'s (2011) framework and conducted interviews with experts to develop the framework further. After performing a Delphi study with 14 sustainability education experts, they suggested two additional competencies to complete Wiek et al.'s (2011) framework (namely: implementation competency, and intrapersonal competency or mindset), with a hierarchy between competencies, as well as with specific learning objectives. Their study offers, to our knowledge, the most recent and updated framework on sustainability key competencies and is based on a consensus among experts on what skills and knowledge are most important for sustainability professionals. **Table 1** provides the definition of such sustainability key competencies.

Table 1. Framework of sustainability key competencies and their descriptions as proposed by Brundiers et al. (2021).

Sustainability key competency	Definition	Source
Systems-thinking competency	The "ability to collectively analyse complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks."	Wiek et al. (2011, p. 207)
Values-thinking competency	The "ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets." "To explain how values are contextually, culturally, and historically reinforced"	Wiek et al. (2011, p. 209) Brundiers et al. (2021, p. 20)
Strategic-thinking competency	The "ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability."	Wiek et al. (2011, p. 210)
Futures-thinking competency	The "ability to collectively analyse, evaluate, and craft rich 'pictures' of the future related to sustainability issues and sustainability problem-solving frameworks."	Wiek et al. (2011, p. 209)
Intrapersonal competency	The "ability to be aware of one's own emotions, desires, thoughts, behaviors, and personality, as well as to regulate, motivate, and continually improve oneself drawing on competencies related to emotional intelligence [...] and social and emotional learning"	Brundiers et al. (2021, p. 20)
Interpersonal competency	The "ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving."	Wiek et al. (2011, p. 211)
Implementation competency	The "collective ability to realise a planned solution toward a sustainability-informed vision, to monitor and evaluate the realisation process, and to address emerging challenges (adjustments), recognising that sustainability problem solving is a long-term, iterative process between planning, realisation, and evaluation"	Brundiers et al. (2021, p. 21)
Integrated problem-solving meta competency	The ability to "combine and integrate steps of the sustainability problem-solving process or competencies, while drawing on pertinent disciplinary, interdisciplinary, transdisciplinary, and other ways of knowing". It is different from the other key competencies in that the integrated problem-solving competency is a meta-competency that represents the capacity to effectively combine and apply the five core key competencies to address sustainability challenges.	Brundiers et al. (2021, p. 22)

Other frameworks for sustainability key competencies also emerged, such as the one by Rieckmann (2018), used in Heras (2022). This framework resembles the one by Wiek et al. (2011) and by consequence by Brundiers et al. (2021), and presents eight sustainability key competencies. It must be noted that Marco Rieckmann is also a co-author of the Brundiers et al. (2021) article. Whereas Rieckmann (2018) included 'critical thinking' as a key competency, the Brundiers et al. (2021) framework does not include it, considering critical thinking to be a foundational skill rather than a key sustainability competency. In addition, Brundiers et al. (2021) include an 'implementation' key competency, which emphasises on the ability to collectively implement the solutions in the long-term, through iterations and collaborations, whereas Rieckmann (2018) does not.

This study has chosen to use the framework of competencies by Brundiers et al (2021), as it stems from the most cited key competencies framework by Wiek et al. (2011). Moreover, as exemplified above, the Brundiers et al. (2021) framework is the latest update of a sustainability key competencies framework developed based on an expert consensus.

2.3. Art in Sustainability education

Several denominations are used across the literature on art in sustainability education to refer to the use of art and art practices in an educational setting: art-based teaching (Wall et al., 2019); arts-based approaches (Wall et al., 2019); aesthetic pedagogies (Heras, 2022); aesthetic learning (Heras, 2022); aesthetic practice pedagogy (Molderez & Ceulemans, 2018); aesthetic practices (Heras, 2022); art-based research (Heras, 2021). For the current study, the term art-based teaching (ABT) will be used to refer to such practices that are deployed intentionally for educational outcomes relevant to sustainability. ABT can encompass diverse practices including visual arts (painting, drawing, sculpture, installation, photography, film), performing arts (drama, theatre, dance, music, storytelling), and literary arts (poetry, creative writing) (Wall et al., 2019; Heras, 2022).

Many studies looked into integrating art for sustainability education, whether by using artworks to convey messages linked to sustainability or encourage critical thinking (Molderez & Ceulemans, 2018), or by allowing students to practice art themselves (Heinrichs, 2021). Across the literature, the role of art in sustainability education is increasingly acknowledged as a means to increase awareness, engagement, as well as action (Heras et al., 2021; Wall et al., 2019;

Heinrichs, 2021; Malytska et al., 2022). Indeed, art provides a way to connect with environmental issues on an emotional and ethical level: it stimulates critical thinking and promotes a deeper understanding of our relationship with the planet and nature (Malytska et al., 2022; Angeler, 2016; Harell et al., 2011; Kaufmann et al., 2023). Further down the line, art-based methods are seen as having the power to transform values and behaviors, leading to a more sustainable way of life (Angeler, 2016; O'Neill & Nicholson-Cole, 2009; Stoll et al., 2022).

Most of the literature has focused on how art can be used to introduce sustainability concepts to learners with little prior knowledge, while fewer focused on art's role within higher education programs where one can assume students are already familiar or interested in sustainability challenges. Jónsdóttir's doctoral thesis *Artistic Actions for Sustainability: Potential of Art in Education for Sustainability* is quite valuable to illustrate the potential of art for sustainability teaching, yet it represents the former type of work (Jónsdóttir, 2017). By contrast, the study by Heinrichs (2021) *Teaching Sustainable Development in a Sensory and Artful Way—Concepts, Methods, and Examples* focuses on how art-based practices can be integrated into courses for sustainability program students.

In their article "Art-based teaching on sustainable development", Wall et al. (2019) introduce ABT as a range of concepts, ideas, and practices that cross several disciplines, including art, education, and sustainable development. Wall et al., (2019) suggest that art can make abstract ecological theory tangible to laypeople, thereby improving comprehension of complex systems and data (Wall et al., 2019). Unlike scientific discourse which often prioritises objectivity and detachment, art can access emotional, sensory, and intuitive dimensions to understanding (Wall et al., 2019). They outline important points to justify the need to further the exploration of art-based education for sustainable development, including encouraging individual consciousness about sustainability and its implications, encouraging ethical values and a sense of responsibility that align with sustainable development goals, and inspiring and driving collective efforts toward sustainable action.

The exploratory study by Molderez & Ceulemans (2018) links the use of art for sustainability education to one of the key competencies, as they focused on exploring how art can foster systems thinking. In this study, paintings were used as a medium for students to critically reflect on the relationship between system and environment. During a course on corporate social responsibility for business students, two paintings were selected to explain top-down sustainability

(approach based on problem-solving to handle societal challenges and where the system is *within* the environment) and bottom-up sustainability (approach based on a critical reflection of current ways of living where the system is *with* the environment). Their results point to the fact that using visual artworks in this context generally helped students achieve better systems thinking by encouraging them to think in patterns instead of looking at separate elements to analyse a complex system. Important to mention is that this study does not entirely correspond to the current study's focus as the higher education students were not from a sustainability program (they were business students), but rather were introduced to sustainability through art.

Heras (2022) conducted a literature review of 13 articles about the integration of art and 'aesthetic learning' interventions for sustainability education. The author collected data on the intervention characteristics, the evaluation methodology, the sustainability topic addressed, and reported outcomes and insights of such interventions. She performed a qualitative content analysis to identify the motivations behind applying the arts and to link the reported learning potentials to sustainability competencies guided by a predefined set of eight key sustainability competencies identified in the literature by Rieckmann (2018), which compiles competencies from six existing frameworks. The findings of this research showed that key motivations included: increasing knowledge and awareness of sustainability challenges, amplifying personal and affective connections with the environment , and promoting a sense of agency and collective action. This research provides a strong basis to support the exploration of art-based interventions to the more specific context of sustainability higher education, and linking potential benefits of such practices to sustainability key competencies.

2.4. Art in Industrial Ecology education

While there is a growing body of research on art in sustainability education, to the best of our knowledge, the integration of art for IE education has not yet been made explicit in the literature. The application of art for IE *research* is also very limited. The main research that touches upon such an approach is that of Eckelman & Laboy (2020) who, through the use of visualisations, make it easier to understand the environmental impact of the construction sector. Eckelman and Laboy (2020) describe a collaborative project developed with engineers and architects to visualise LCA results using human scale photo-realistic images which are quantitatively accurate. The authors

argue that traditional quantitative visualisations, although scientifically accurate, often fail to resonate emotionally or intuitively with non-experts. They address this gap [by creating human-scale, photorealistic images that depict environmental data in familiar everyday settings. For example, an image may represent a gigantic water glass towering over a building to visually convey resource consumption and emissions (Eckelman & Laboy, 2020). Their research is an important stepping stone for the integration of art in IE research and education, and also forms a strong basis for this study's argumentation. However, their approach remains in the realm of scientific visualisation using conventional tools. In addition, although their article demonstrates how art can be used for IE research, and seems to be the only one doing that in the available scientific literature, it does not specifically address IE educational practices.

Chapter 3. Research approach

This exploratory study employed a two-stage qualitative methodology, consisting of a systematic literature review on the one hand, and an empirical data collection through interviews on the other hand. Both methods aimed at recording ABT cases, the unit of analysis of this study. A systematic literature review was carried out to investigate various ways in which art has been used within SHE, examining existing applications of ABT within SHE (SRQ1), and exploring both the benefits and challenges of these activities (SRQ2 and SRQ3). The same was done through an empirical data collection through a series of interviews focusing specifically on educators and students from graduate IE programs. These interviews served as a bounded case study to provide insights into how art-practices were implemented and/or experienced within the specific context of IE curricula (Stake 1995). Finally, based on the findings from the literature review and empirical data collection, a link to the sustainability key competencies is drawn with the use of ABT practices in SHE settings (SRQ4). **Figure 1** outlines the research methods and objectives of this study.

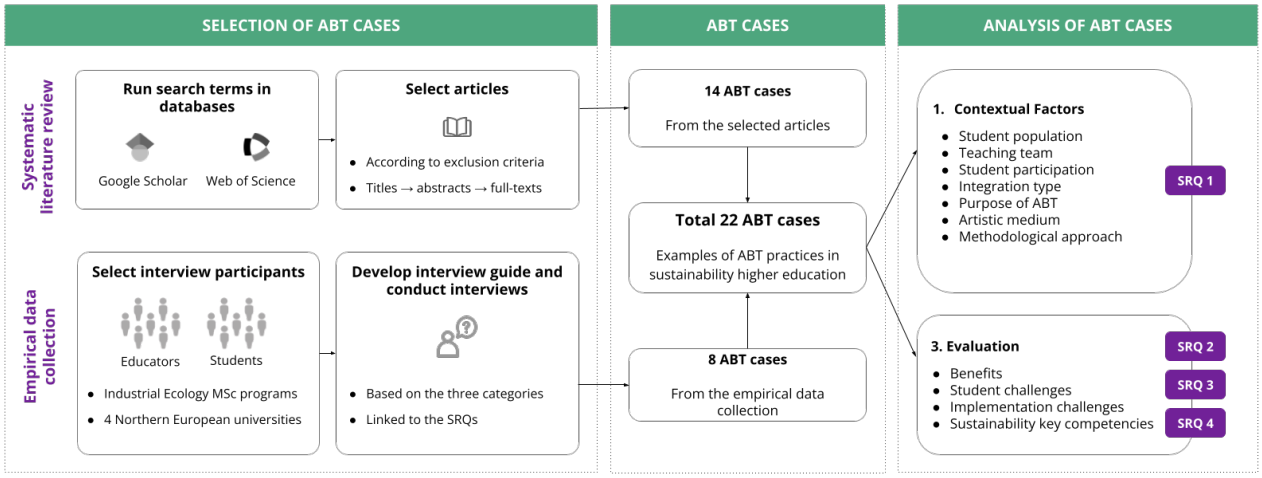

Figure 1. Study's research flow diagram, aligned with the different phases of research outlined in the timeline.

This section is divided into two parts, reflecting the methods used for the research. First, subsection 3.1 describes the systematic literature review process employed to select relevant

articles from the scientific literature. Second, in subsection 3.2., the empirical data collection process is also described, outlining the sampling procedure and the interview participants profiles.

3.1. Systematic literature review

3.1.1.Unit of analysis, population, and sample

The unit of analysis for the systematic literature review is individual courses, workshops, or classes within SHE, referred to as ABT cases throughout this study. The population under consideration is SHE courses worldwide, encompassing a wide range of disciplinary and pedagogical contexts. The sample consists of peer-reviewed academic studies that describe such courses, their characteristics and contextual factors.

3.1.2. Selection of papers

First, a systematic literature review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines by Page et al. (2021) was performed. This method includes an identification, a screening, and an inclusion phase (Page et al., 2021). In the identification stage, the search terms presented in **Table 2** were entered in the databases Web of Science and Google Scholar.

Table 2. Search terms for the systematic literature review.

"Art-based"	AND	"industrial ecology"	AND	"higher education"
"art"		"environmental*"		"teach*"
"artist*"		"sustainab*"		"learn*"
"STEAM"				

The screening stage followed and was done according to a set of inclusion and exclusion criteria (**Table 3).** First, titles and abstracts were screened, after which full texts were read and finally selected for analysis if they matched the inclusion criteria.

Table 3. Inclusion and exclusion criteria for article selection.

Inclusion criteria	Exclusion criteria
1. Available in English, French, or Spanish	1. Not available in English, French, or Spanish
2. About higher education	2. Is a duplicate
3. About sustainability programs	3. Not open access
4. Include art-based teaching approaches	4. Not about higher education
	5. Not about sustainability-focused programs
	6. Does not include (an) art-based approach(es)
	7. Retracted article
	8. Not peer-reviewed journal article
	9. Is a review paper
	10. Paper does not include a case study

In addition to searching for articles in the two databases, both backward and forward citation chaining were conducted. This involved screening the reference lists of the selected papers to identify relevant prior studies (backward citation chaining), as well as reviewing subsequent publications that cited these papers after their publication (forward citation chaining), all in accordance with the established inclusion criteria (Hirt et al., 2024). Although review papers were excluded from the selection, their reference lists were screened and they were the basis for the backward and forward citation chaining process. The final PRISMA diagram presenting the selection of included articles is showcased in **Figure 2.**

There were more than 500 results on the databases, and with the citation chaining. A great majority of these were excluded after screening for titles, as many resulting articles were about the state-of-the-art of machine learning, because of the two search terms ‘art’ and ‘learn*’. The main reasons for exclusion of full-texts were reason 4 (‘Not about higher education’) and reason 6 (‘Does not include an art-based approach(es)’).

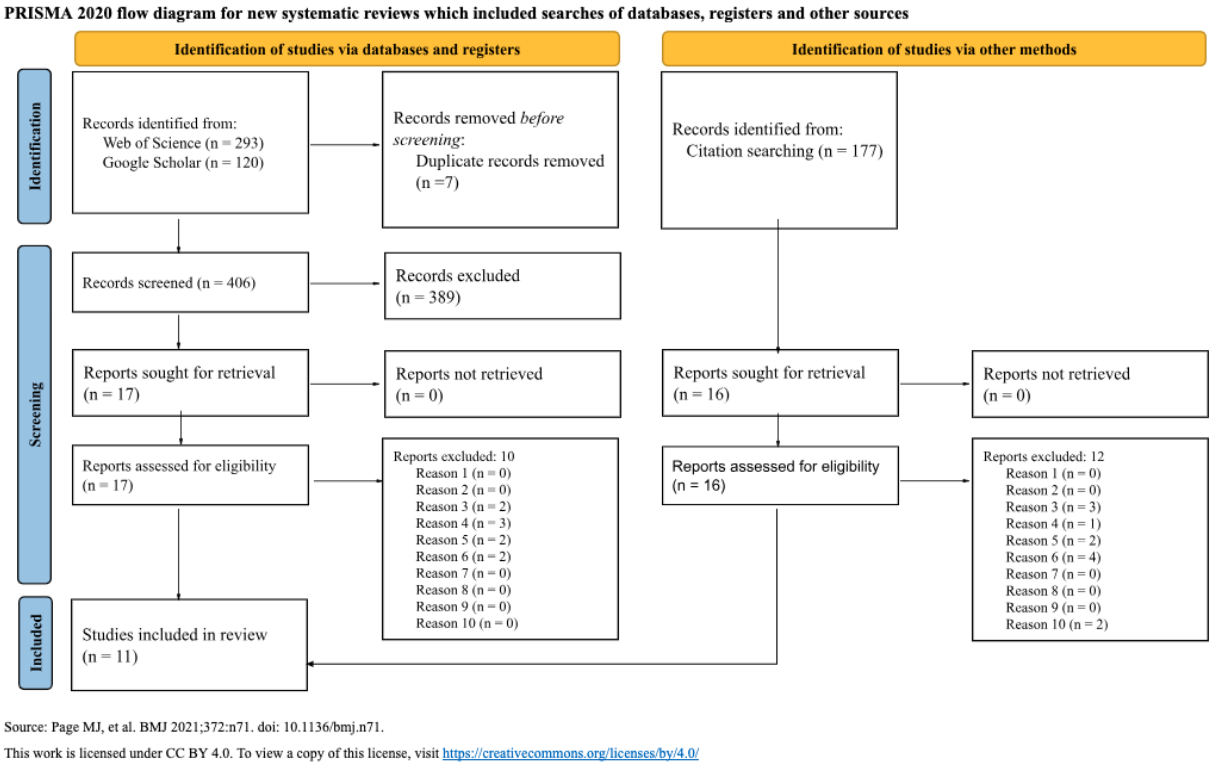

Figure 2. PRISMA diagram summarising the selection process and outcomes of the systematic literature review.

3.1.3. Analysis of the selected papers

The selected papers were analysed using the same dimensions used by Heras (2022) and based upon a first screening of the literature (**Table 4**). Whilst Heras (2022) focused on a broader target group including children, youth, and adults, this literature review focused solely on higher education students from sustainability programs. Moreover, although Heras (2022) clearly discusses the challenges and opportunities that these cases highlighted for the integration of artistic approaches, the present study systematically assesses the selected records to record challenges and benefits linked to both the learning experience of students, and to the practical implementation of such methods to higher education students.

Table 4. Categories and dimensions used to systematically analyse the selected peer-reviewed articles. Descriptions of each dimension are provided, as well as the sources from which they were drawn.

Category	Dimension	Description	Sources and justification
1. Contextual factors and ABT intervention	(1) Student population	Higher education level and program; group size.	Heras (2022) Clarifying context, discipline, and scalability of the intervention.
	(2) Teaching team	Size of teaching team, disciplinary background and expertise.	Heinrichs (2021) Showing how educator expertise shapes the approach. The source suggests that this aspect has an impact on the success of a class using art-based approaches.
	(3) Student participation	Participatory (active creation) vs. non-participatory (interpretive/audience).	Heras (2022); Jónsdóttir (2017) Different modes of art integration (active vs. passive) affect student experience, learning outcomes, and ease of implementation.
	(4) Integration type	Standalone project vs. integrated course component.	Heras (2022) The source describes how art-based methods were embedded indicating the intervention's duration and depth.
	(5) Purpose of art integration	Stated educational goals for using artistic methods.	Heras (2022) Recording the motivation behind the artistic intervention clarifies learning outcomes and can provide a possible link to key competencies.
	(6) Artistic medium	Type of art used (visual, audiovisual, photography, sound, sculpture, performance, etc.)	Heras (2022) Identifying a range of artistic activities used in various contexts of sustainability higher education.
2. Evaluation	(7) Reported / perceived benefits	Positive learning or pedagogical outcomes for students.	Heras (2022); Identifying the intervention outcomes which would encourage the integration of art in sustainability higher education.
	(8) Student challenges	Highlights learning difficulties and support needs and obstacles related to the practical deployment of the intervention.	Heras (2022) Highlighting learning difficulties and student perspectives and assessing practical barriers to deployment.
	(9) Link to sustainability competencies	Mention of outcomes related to Brundiers et al. (2021) key competencies in sustainability.	Heras (2022) The source compared outcomes with the competencies framework by Rieckmann (2018), while the comparison in this study will be based on Brundiers et al. (2021).

The analysis process combined both a deductive approach relying on predefined dimensions (i.e., the category 'contextual factors and ABT intervention') and an inductive, multi-phase approach, for the 'evaluation' category. Information related to the 'contextual factors and ABT intervention' category of **Table 4** were classified in an Excel table whereas the dimensions from the evaluation category (i.e., benefits; student challenges; implementation challenges; and key competencies) were coded on the software Atlas.ti (ATLAS.ti version 23.2.1).

A qualitative content analysis was conducted to identify (perceived) benefits and challenges of integrating art practices into sustainability higher education. The analysis followed an inductive approach, where data was coded without relying on a predefined coding frame (Stevens, 2023). Interviews and articles were read sequentially, and for each document, specific mentions of benefits, challenges, and key competencies were identified and coded. As analysis progressed, new codes were generated when new meanings or expressions emerged, while existing codes were reused when applicable. This process resulted in a total of approximately 50 initial codes across all sources. After completing the dataset, codes were reviewed for overlaps and redundancies, and similar codes were merged to create a more concise and coherent coding frame (Stevens, 2023). An example of open codes emerging from raw data is given in **Table 5.**

Table 5. Examples of open codes developed through qualitative content analysis of selected cases from articles.

Dimension	Raw data	Open code	Source
(7) Benefit	"the incorporation of role-play and applied theatre processes might be used to create an engaging 'life-like' context that might increase the interest and involvement of the participants."	Increased student engagement	Davis & Tarrant (2014)
(8) Challenge	"The existing tension between open-minded, creative search for research subjects and content-related (sustainability issues) [...] need to addressed proactively"	Tension between artistic/scientific thinking	Heinrichs (2021, p.9)

As stated in section 2.3, two studies explicitly link the use of art and sustainability key competencies (Molderez & Ceulemans, 2018; Heras, 2022). On the one hand, the study by Molderez & Ceulemans (2018) is quite transparent about how they linked the outcomes of the art intervention to key competencies, using a dedicated section in their survey to students asking how

the ABT intervention helped them in better understanding systems thinning. For consistency, benefits identified from both sources were linked to key competencies post hoc. The study by Heras (2022) explicitly attempts to link ABT outcomes to sustainability key competencies, though their approach is not fully detailed, stating that they "conducted a qualitative content analysis to (1) identify motivations underlying the reviewed educational experiences; (2) link learning and educational potentials of these experiences with competencies for sustainability," informed by the eight competencies by Rieckmann (2018). For this study, to link ABT practices with sustainability key competencies, the benefits that had been coded were used, and the text segments corresponding to each benefit were subsequently linked to the relevant competencies, by constantly looking at the definitions. A second layer of qualitative content analysis was applied to establish these connections, and specific raw data from benefits are linked to key competencies in a matrix table in **Appendix C**.

3.2. Empirical data collection

Semi-structured interviews were conducted to gather real-life experiences from educators and students from IE graduate programs. Interviews allowed open-ended discussions, giving space for participants to elaborate on their thoughts, and ultimately providing qualitative data to complement the data from the systematic literature review (Shackleton et al., 2021). For both educators and students, the aim of the interviews were to gather information: concerning previous or current integration of art-based approaches in their educational activities (SRQ1); on the potential benefits and challenges of these approaches for the students' learning and in terms of practical implementation (SRQ2 and SRQ3); and on potential links to sustainability key competencies (SRQ4).

3.2.1. Unit of analysis, population, and sample

Similarly to the systematic literature review, the unit of analysis was courses, workshops, and classes that integrated ABT, but within the specific field of IE. They are also referred to as ABT cases throughout this study. The population was European IE higher education courses, and the sample consisted of educators and students from four European IE programs.

3.2.2. Sampling of interview participants

Educators and students were interviewed as these two groups occupy distinct roles within the educational environment and their perspectives offer insights to map the (potential) benefits and challenges to using art and art practices in the classroom (**Tables 6** and **7**).

Educators, on the one hand, are responsible for designing, implementing, and evaluating educational programs. Their input was important to assess the feasibility of integrating artistic approaches within existing course structures and learning objectives. They provided perspectives on pedagogical strategies, institutional priorities, and the practical challenges that came with introducing new methods into IE curricula. On the other hand, interviewing students reflected on the learning experience from the inside out. Their perspectives helped in understanding how artistic approaches could apply in practice, and how these methods could help their comprehension of sustainability concepts..

The four graduate programs included were:

- M.Sc. Industrial Ecology at Leiden University and TUDelft
- M.Sc. Industrial Ecology at Chalmers, Sweden
- M.Sc. Sustainable Technology at KTH, Sweden.
- M.Sc. Industrial Ecology at NTNU, Norway

Participants for the interviews were selected through a combination of purposive and convenience sampling with the aim of including both individuals who had direct experience with or insights into art-based educational interventions in higher education, and some who did not (Hossan et al., 2023; Horvath et al., 2025). At Leiden University, student participants were recruited via email and personal student networks. Educators from NTNU and Chalmers were contacted by email, while students from these institutions represented the most difficult group to reach. Despite additional outreach through social media platforms, only a few NTNU and Chalmers students agreed to participate.

Table 6. Summary of educator participants included in the study and their related universities, departments, and expertise. (With NTNU = Norges Teknisk-Naturvitenskapelige Universitet)

Name	University	Department	Expertise
Edu 1	Leiden University	Industrial Ecology	Life Cycle Assessment
Edu 2	Leiden University	Industrial Ecology	Life Cycle Assessment
Edu 3	Leiden University	Industrial Ecology	Material Flow Analysis
Edu 4	Leiden University	Industrial Ecology	Circular Economy
Edu 5	Chalmers University	Technology Management and Economics	Life Cycle Assessment
Edu 6	Chalmers University	Architecture and Civil Engineering	Material Flow Analysis
Edu 7	NTNU	Energy and process engineering	Life Cycle Assessment

Table 7. Summary of student participants included in the study and their related universities, undergraduate programs, and current year of study. (With NTNU = Norges Teknisk-Naturvitenskapelige Universitet, and KTH = Kungliga Tekniska högskolan)

Name	University	Undergraduate program	Current year of study
Stu 1	Leiden University	B.Sc. Industrial Design and Product Engineering	Second year
Stu 2	Leiden University	B.Sc. Mechanical Engineering	Second year
Stu 3	Leiden University	B.Sc. Urban Studies	First year
Stu 4	Chalmers University	B.Sc. Material Technology	First year
Stu 5	Chalmers University	B.Sc. Global Systems	First year
Stu 6	KTH	B.Sc. Liberal Arts and Sciences	First year
Stu 7	NTNU	B.Sc. Material Technology	Second year

3.2.3. Interview guides

Two interview guides were developed for the semi-structured interviews; one for educators (**Appendix A1**) and one for students (**Appendix A2**). Each guide includes an outline of the planned topics and questions to be addressed in a tentative order. While both groups addressed overlapping themes related to the integration of art-based approaches in sustainability education,

the guides were adapted to reflect the unique perspectives and experiences of each group (Wholey, 2010).

The interview guides are based on the initial results from the systematic literature review. The categories and dimensions used to systematically analyse the literature (**Table 4**) were used to formulate the interview questions, which also facilitates the analysis of the interviews which will follow the same process as the one for the literature review. The interview questions were also aligned with the research questions. **Table 8** shows the alignment of the interview questions with the categories, dimensions, and research questions formulated for this study.

Because of the nature of semi-structured interviews, and as some follow-up questions might be asked and some clarifications needed, some questions could be asked in a different order, however, the guide was meant to be structured in a coherent way in order to anticipate conversation flow (Wholey, 2010). In addition, the interview guide has been reassessed throughout the interview research phase as new insights could occur leading to a needed refinement of the guides (Wholey, 2010). The interview guides have been reassessed after the first interview, and periodically after.

Table 8. Alignment of interview questions with categories, dimensions and research questions for the educator interview guide (Edu Q*n*) and student interview guide (Stu Q*n*). In each cell are the corresponding numbered dimensions linked to the categories in the second row, as outlined in Table 4.

	SRQ1		SRQ2	SRQ3	SRQ4
Category	Contextual Factors and ABT intervention		Evaluation		
Edu Q0	(2) Teaching team				
Edu Q1	**Description of the ABT intervention** (1) Student population (3) Student participation				
Edu Q2		(4) Integration type			
Edu Q3		(5) Purpose of art integration			
Edu Q4		(6) Artistic medium			
Edu Q5					(9) Link to competencies
Edu Q6			(7) Reported / perceived benefits		(9) Link to competencies
Edu Q7				(8) Reported / perceived challenges	
Stu Q0	(1) Student population				
Stu Q1	Description of the ABT intervention (2) Teaching team (3) Student participation				
Stu Q2		(4) Integration type			
Stu Q3		(5) Purpose of art integration			
Stu Q4		(6) Artistic medium			
Stu Q5					(9) Link to competencies
Stu Q6			(7) Reported / perceived benefits		(9) Link to competencies
Stu Q7				(8) Reported / perceived challenges	

Question 0b. of the educators' interview guide is not explicitly recorded in the teaching expertise dimension for the literature review analysis (see **Appendix A1**). This is because papers do not make the teaching style of educators in their case studies or analyses explicit. However, Heras

(2022, p. 152) suggested that art-based practices often required "*inquiry-based pedagogies, opening-up processes of exploration and inquiry, including in some cases participatory action-research, as well as place-based pedagogies, with an emphasis on the spaces where the learning takes place*." Thus, with this question, we explore the predispositions of professors' style in teaching for incorporating art-based approaches to their courses. Scarff Seatter & Ceulemans (2017) also suggest that transformative learning is a crucial outcome for effective HEfSD, and teaching styles vary in their capacity to facilitate this. Hence, getting an overview of professors' teaching style can help gauge whether there is an existing leeway for transformative learning.

3.2.4. Conducting the interviews

A total of 14 interviews were conducted in the period May to June 2025. Prior to conducting the interviews, informed consent forms were provided to each participant and signed in accordance with the rules and regulations of Leiden University for social and human research. Participants were also clearly informed of the research goals. In addition, all participant data was kept confidential and anonymised. Eight interviews were conducted in person, including all participants from Leiden University, and one participant from KTH. All other interviews were conducted online.

3.2.5. Analysis of the empirical data

The analysis of the interview data followed three steps. The first step consisted in identifying the ABT cases that could be used for the categorisation of the contextual factors and ABT intervention category. This was done according to the exclusion criteria developed for the selection of articles in the literature review. This means that cases should be examples of courses, or workshops where art was used either as a support or actively engaged with by students from sustainability higher education programs or courses. Second, the benefits and challenges mentioned in the interviews were taken into account in this study regardless of whether they specifically stemmed from the use of ABT in classes. That is to say, all the perceived benefits and challenges mentioned by participants were coded and analysed. Therefore, the benefits and challenges frequencies were no longer referred to in relation to the number ABT cases from the interviews, but to the total number of interviews.

The coding of the evaluation dimensions for the empirical data followed the same coding process as the articles, as shown in **Table 9**.

Table 9. Example of open codes developed through qualitative content analysis of the empirical data collection.

Dimension	Raw data	Open code	Source
(7) Benefit	"It has been very helpful to understand other perspectives and it should be used like this."	Broadening perspectives	Stu 5
(8) Challenge	"I find that very hard to grade because I want to reward the creativity that goes into it"	Assessment criteria of art content	Edu 4

As for the link to key competencies, the same approach was used as described in section 3.1.3, namely a second qualitative content analysis categorising benefits into the key competencies framework of Brundiers et al. (2021) through raw data.

Chapter 4. Results

This chapter presents the qualitative data collected and analysed from the 22 selected ABT cases mentioned in both the literature review and the interviews that included ABT in a SHE context. Each article and interview could provide more than one example of ABT practice integration. For the interviews, it could also be that no example is provided, if the participant had never integrated or never experienced ABT practices in the classroom.

The chapter is organised in four sections, according to the study's four sub-research questions. Current practices of art in SHE, including their contextual factors, are presented in section 4.1 (SRQ1). In section 4.2, we introduce the benefits reported in the reviewed literature on SHE and in the interviews conducted with IE educators and students, while in section 4.3, reported challenges are displayed (SRQ2 and 3). Finally, the link to sustainability key competencies is introduced in section 4.4 (SRQ4). Each section separately presents the results from the systematic literature review on SHE, and the ones from the empirical data collection of the IE case study.

4.1. Current art practices in sustainability higher education

This section presents the results from the reported contextual factors and ABT interventions, divided into six dimensions as shown in **Table 4** (Chapter 3). These results and dimensions address SRQ1 on how and why art has been used in SHE. The overview table linking the ABT cases with their sources, the student population factors and the teaching team is displayed in Table B1 (**Appendix B**).

4.1.1. Student population

The student population dimension looked at group sizes of each case study, as well as the higher education programs the student participants were enrolled in. Results from that dimension are presented in **Table 10.**

Table 10. Overview of ABT cases' student population composition. The table presents the ABT cases' group sizes, the program level, the name of the programs in which the students were enrolled, and whether the case study included students from one (single-program) or several (multi-program) study programs. In purple, the ABT cases recorded from the interviews, in black, those recorded from the selected articles from the literature review.

Case study	Group size	Program level	Program	Cohort composition
The Material City	50	Undergraduate	Urban Studies	Single-program
Material Flow Analysis	36	Graduate	Industrial Ecology; Energy and Environment	Multi-program
Transdisciplinary approaches for system innovation	30	Graduate	Sustainable Technology	Single-program
Term wrap-up session	30	Graduate	Industrial Ecology	Single-program
Blue Engineering	25	Graduate	Industrial Ecology	Single-program
Environmental and Global Capitalism	20	Graduate	Political Sciences; International Relations; Industrial Ecology	Multi-program
Sustainability Analytics and Visualisation	15	Graduate	Industrial Ecology	Single-program
Socio-economic Metabolism	not specified	Graduate	Industrial Ecology	Single-program
Productive Management	51	Undergraduate	Biochemistry and Pharmaceuticals; Environmental Management	Multi-program
Environmental Education	50	Graduate	Science Education	Single-program
Workshop on emergence	37	Undergraduate	Art and Technology; Environmental Management and Sustainability Science	Multi-program
Designing Livable Housing in Taiwan	33	not specified	Design, Management, Information, and Applied Society	Multi-program
Sustainability, Politics, Everyday Life	25	Undergraduate	Cultural Studies; Environmental Studies; Engineering; Pedagogical Studies	Multi-program
Dancing Urban Waters	20	Graduate	Civil Engineering and Management	Single-program
Bureau of Expertise	20	Undergraduate	Cultural Studies; Environmental Studies; Social Sciences; Pedagogical Studies	Multi-program
Sound of Sustainability	15	Undergraduate	Cultural Studies; Environmental Studies; Psychology; Business Administration	Multi-program
Urban Ecologies, Urban	not specified	Graduate	Urban sustainability and	Single-program

Economies			Resilience	
Natural Resource, Ecological & Environmental Economics	not specified	Undergraduate	Economics, Sustainability & Society; Environmental Science; Land, Farming, and Community; Sustainability: Economics & Management; Environmental Studies minor	Multi-program
Architectural Concepts of Airport Sustainability	not specified	Graduate	Architecture; Environmental Management	Multi-program
The Noosa Spit Development	not specified	Graduate and Undergraduate	Global Programs in Sustainability	Multi-program
Multiple Ways of Knowing in Environmental Decision-Making	not specified	Graduate	Environment and Sustainability	Single-program
Introduction to Environmental Art Education	not specified	Undergraduate	Social sciences; natural sciences; arts studies	Multi-program

Results from the empirical data on IE education context

For the eight ABT cases extracted from the interviews, group sizes ranged from 15 to 50 students, with one case not specifying the number of participants. Five of these were courses or workshops attended exclusively by IE students or equivalent (e.g., M.Sc. Sustainable Technology). As for the other three ABT cases, "The Material City" was a compulsory course for undergraduate Urban Studies students (still attended by students from a single program), the course "Environmental and Global Capitalism" was an elective course welcoming IE, political sciences, social sciences, and international relations students of Leiden University, and the Material Flow Analysis course had IE and Energy and Environment students, thus both categorised as having a multi-program cohort composition. Seven of the eight ABT cases were courses or workshops for graduate students, with the exception of "The Material City" course which was offered to undergraduates.

Results from the systematic review on SHE context

In the ABT cases identified through the literature review, group sizes ranged from 15 to 51 students per session, with five cases not specifying the size of the groups. Seven of the 14 ABT cases were conducted with undergraduate students, five with graduate students, and one included both undergraduate and graduate students, and one ("Designing Livable Housing in Taiwan") did not specify the program level. In terms of cohort composition, 10 of the ABT cases included students from multiple programs, while four were attended exclusively by students from a single program.

4.1.2. Teaching team

The teaching team dimension focused on the ABT cases' teaching team sizes, as well as the educators expertise. Results for that dimension are presented in **Table 11.**

Table 11. Overview of ABT cases' teaching team, specifying the teams' sizes and the educators' expertise. In purple, the ABT cases recorded from the interviews, in black, those recorded from the selected articles from the literature review.

Case study	Team size	Expertise
The Material City	2	Industrial Ecology
Material Flow Analysis	3	Industrial Ecology
Transdisciplinary Approaches for System Innovation	2	Industrial Ecology
Term wrap-up session	1	Industrial Ecology
Blue Engineering	4	Industrial Ecology
Environmental and Global Capitalism	1	International Relations
Sustainability Analytics and Visualisation	2	Industrial Ecology
Socio-economic Metabolism	2	Industrial Ecology
Productive Management	2	Biology
Environmental Education	1	Science education
Workshop on emergence	2	Social sciences; Environmental assessment
Designing Livable Housing in Taiwan	1	Environmental education
Sustainability, Politics, Everyday Life	2	Sustainability; Documentary filmmaker
Dancing Urban Waters	2	Social sciences; Performance artist
Bureau of Expertise	2	Sustainability; Visual artist
Sound of Sustainability	2	Sustainability; Sound artist
Urban Ecologies, Urban Economies	1	not specified
Natural Resource, Ecological & Environmental Economics	1	Economics and sustainability
Architectural Concepts of Airport Sustainability	3	Aviation and environment; architecture
The Noosa Spit Development	2	Sustainability; Drama
Multiple Ways of Knowing in Environmental Decision-Making	2	Sustainability

Results from the empirical data on IE education context

For the eight ABT cases drawn from the interviews, teaching teams ranged from one to four educators, with half involving two instructors. In line with the interview sample, most courses were taught by IE professors, with the sole exception of "Environment and Global Capitalism," taught by an International Relations professor. None of the interview cases involved formal collaboration with artists.

Results from the systematic review on SHE context

In the ABT cases identified through the literature review, teaching teams also ranged from one to three educators, with over half involving two instructors. The disciplinary expertise of educators covered natural sciences, engineering, social sciences, and art. Six of the 14 cases featured interdisciplinary collaborations between sustainability educators and artists. Examples include "Sustainability, Politics, Everyday Life" (Heinrichs, 2021), "Dancing Urban Waters" (Bruzzone & Stridsberg, 2023), and "Noosa Spit Development" (Davis & Tarrant, 2014).

4.1.3. Student participation

In terms of student participation, the ABT cases were classified as either participatory, or non-participatory. If the ABT intervention involved the active participation of students in which they create pieces of art, then the practice was labelled as participatory. If the ABT involved using art as a support for a discussion with the students (either by the educators or by a group of students not having created that piece), then it was labelled as non-participatory. For classes that included both ABT interventions that were participatory and non-participatory, for instance because a course included different class exercises, then it was categorised as 'both'. The results of that categorisation is displayed in **Figure 3.**

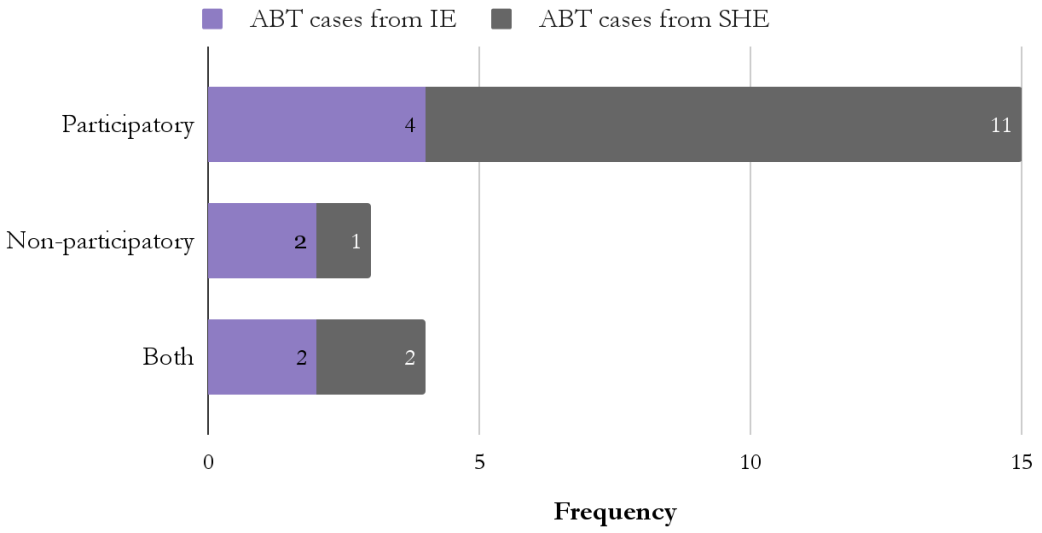

Figure 3. Frequencies of ABT cases with participatory, non-participatory, or both types of student participation out of 22 ABT cases included in this study's analysis.

Results from the empirical data on IE education context

In regards to ABT cases in IE, four were participatory whilst two were non-participatory and two were employing a mix of both participatory and non-participatory approaches. Forms of participatory ABT included creating artefacts during a workshop ("Term wrap-up session"), making videos and writing future scenarios ("The Material City"), or creating a performance involving spoken words and body movements ("Blue Engineering"). An example of a non-participatory way of including art in a course was given by Stu 3 about the course "Environment and Global Capitalism", where the student used poetry as a support to start a discussion with the class, a poem they had not written themselves. This was also the case for the example about the "Material Flow Analysis" class given by Stu 7, which included a painting from the 17th century that, again, was used as a support for discussion with the rest of the class.

Results from the systematic review on SHE context

Most ABT cases analysed from the literature were participatory (11 out of 14), whilst one was non-participatory and two were both participatory and non-participatory. In Moreira Palacios et al. (2017), students used music video clips to discuss sustainability issues, which thus was categorised as non-participatory. The 'Noosa Spit Development' case study employed a mix of participatory and non-participatory ABT practices. On the one hand, as students walked in the Noosa area, they

came to meet long-term residents who took up characters such as businessmen or fishermen and interacted with them, which, for the students, was non-participatory. On the other hand, the students themselves later portrayed these characters in a role-play debate with stakeholders from the region, which was then a participatory practice.

4.1.4. Integration type

To analyse and categorise ABT cases' art integration type, four categories were inductively developed, based on the ABT cases' description of ABT integration. The four categories are: art integrated through graded assignments, class exercises, dedicated workshops, or as the central focus of an entire course. Although in the latter category art may also have been implemented through specific exercises or assignments, this classification was used to distinguish between courses that integrate art in a holistic manner and those that do so in a more limited or activity-specific way.

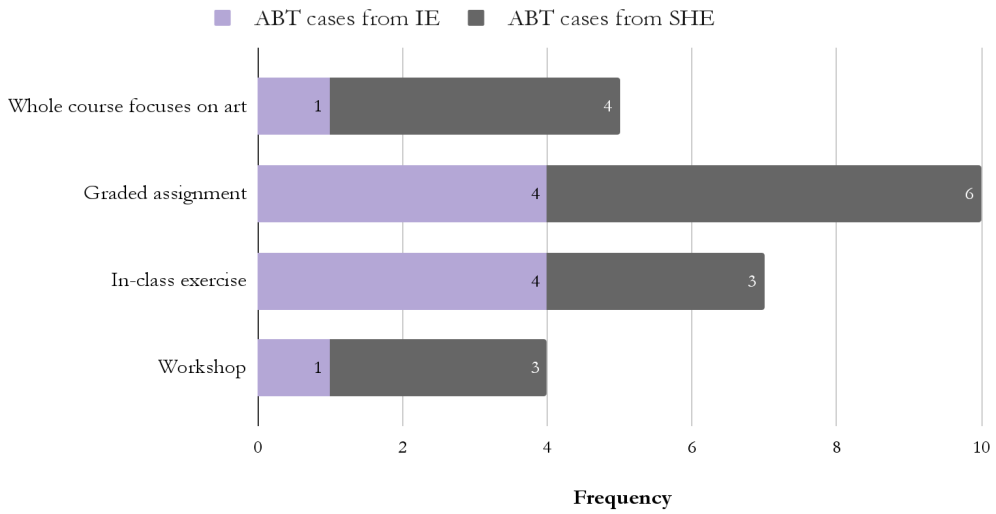

Figure 4. Frequencies of integration types for art out of 22 ABT cases included in this study's analysis.

Results from the empirical data on IE education context

An equal number of cases from IE integrated art in graded assignments and in in-class exercises (four cases each) (**Figure 4**). One case was a workshop, the "Term wrap-up session" provided by Edu 5. The course "Sustainability Analysis and Visualisation", was the only example from IE of a course focusing on integrating scientific and artistic methods for sustainability communication.

Results from the systematic review on SHE context

Most cases (6 out of 14 from the selected articles in the review) integrated art in graded assignments. A total of four cases focused on the integration of art with sustainability, three incorporated art into class exercises, while three were workshops, meaning they were a one-time extracurricular session, with no graded assignment. This was the case for the "Workshop on Emergence" in Heinrich & Kørnøv (2022), the "Green Airport Design Evaluation" (Haley et al., 2017), and "Dancing Urban Waters" (Bruzzone & Stridsberg, 2023).

4.1.5. Purpose of ABT intervention

Similarly to the previous dimension (integration type), this dimension relied on inductively developed purposes (see subsection 3.3.2). This resulted in ten purposes, displayed in **Figure 5,** showing the ABT cases' main reason for integrating ABT in their courses or workshops. The total frequencies do not amount to the total number of ABT cases analysed (i.e., 22 cases), as one ABT case could mention several purposes.

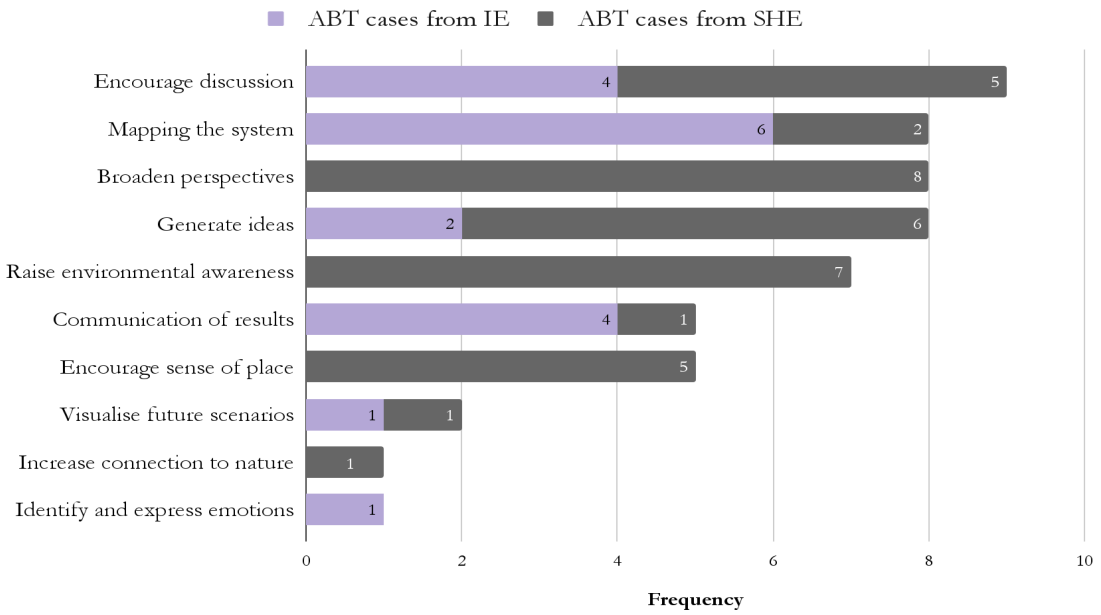

Figure 5. Frequencies of identified purposes for integrating art in the ABT cases. The data is based on the proportion of ABT cases that mentioned each purpose, categorised into ten thematic purposes.

Results from the empirical data on IE education context

For the IE cases, the most mentioned purpose was ‘mapping the system’, mentioned for six courses or workshops. This is followed by the purposes ‘encourage discussion’ and ‘communication of results’, both mentioned in four cases. The purpose ‘generate ideas’ was mentioned twice, whilst ‘visualise future scenarios’ an ‘ identify and express emotions’ were both only mentioned once. Finally, four purposes were not mentioned at all, while they were mentioned in cases from the literature. These are: ‘broaden perspectives’; ‘raise environmental awareness’, ‘encourage sense of place’; and ‘increase connection to nature’.

Results from the systematic review on SHE context

The three most mentioned purposes in the ABT cases from SHE articles were ‘broaden perspectives’ (8 out of 14 cases), ‘raise environmental awareness’ (7 out of 14 cases), and ‘generating ideas’ (6 out of 14 cases). Three purposes had only one mention: ‘communication of results’, ‘visualising future scenarios’, and ‘increase connection to nature’. Finally, the purpose ‘identify and express emotions’ was not mentioned in the articles.

4.1.6. Artistic medium

Figure 6 displays the range of artistic mediums recorded for each case study, and the mediums’ frequency. These findings remain indicative and have not been subjected to statistical testing.

	Visual					Literary		Performance		Audiovisual / Multimedia			
	Drawing	Collage	Graphic design	Photography	Artefact	Creative writing	Poetry	Performance	Dance	Video	Sound clip	Music	Artistic installation*
The Material City						X				X			
Material Flow Analysis	X												
Transdisciplinary approaches for system innovation		O	O							O			
Term wrap-up session					X								
Blue Engineering		O	O					O					
Environmental and Global Capitalism							O						
Sustainability Analytics and Visualisation	O		X										
Socio-economic Metabolism	X												
Productive Management										X		X	
Environmental Education					O	O	O			O		O	
Workshop on emergence													X
Designing Livable Housing in Taiwan			X										
Sustainability, Politics, Everyday Life										X			
Dancing Urban Waters									X				
Bureau of Expertise	X		X										
Sound of Sustainability											X		
Urban Ecologies, Urban Economies										X			
Natural Resource, Ecological & Environmental													
Green Airport Design Evaluation	O	O								O			
The Noosa Spit Development								X					
Multiple Ways of Knowing in Environmental		O	O	O		O	O						
Introduction to Environmental Art Education					O								
Frequency	5	4	6	1	3	3	3	2	1	7	1	2	1

*In Heinrich & Kørnøv (2022), the students are asked to design an artistic installation that would sensitise an audience to a sustainability issue. This artistic installation could take any form and thus was added in this study as a distinct category because of its scale and the various mediums it can integrate.

Legend

X Mandatory art form (ABT cases from IE)

O Optional art form (ABT cases from IE)

X Mandatory art form (ABT cases from SHE)

O Optional art form (ABT cases from SHE)

Used for a class exercise

Used for an assignment

Used for both a class exercise and and assignment

Used for a workshop

Figure 6. Overview of artistic mediums used in each ABT case, and their frequency. If a specific artistic medium was required by the course or workshop, then it is marked by an X in the table. If, however, the case study did not make any artistic medium mandatory but left it open for students to choose, then the artistic medium is marked by an O for the respective case study. In purple, ABT cases from IE, and in black cases from the SHE context.

Columns - The columns display the range of artistic mediums used in ABT cases. These mediums were characterised as either visual, literary, performance, or audiovisual/multimedia art forms. Looking at the columns informs us on:

- which artistic mediums were used in the ABT cases;
- which art form (e.g., visual, literary, performance…) displays the most artistic mediums;
- which artistic mediums were most used over all ABT cases, by looking at the frequencies on the bottom row
- whether these art forms were mandatory (marked by an X) or optional (marked by an O);
- the integration type of that artistic medium (assignment, class exercise, workshop).

In total, 13 different artistic mediums were mentioned and used in the ABT cases. Five mediums were visual art forms (drawing, collages, graphic design, photography, and artefacts), two were literary art forms (creative writing and poetry), two were performance art (performance and dance), and four were audiovisual/multimedia art forms (video, sound clip, music, and artistic installations). To get an idea of which art form (i.e., visual, literary, performance, audiovisual/multimedia) is most used in the ABT cases, we can derive the average mentions per medium: with 19 mentions over five categories, visual art forms have an average of 3.8 mentions which makes them the most frequently used mediums in ABT cases, followed by literary arts (with on average 3 mentions per medium), then audiovisual/multimedia art forms (with 2.8 average mentions per medium), and finally performance arts (with 1.5 average mentions per medium).

Video was the most mentioned artistic medium throughout ABT cases, with seven mentions of its use, followed by graphic design with six ABT cases mentioning that medium. The least frequently used mediums were photography, dance, and artistic installations, each mentioned by one ABT case.

Collages, photography, and poetry were the only three art mediums that were always optional in ABT cases, and never imposed on students. In contrast, dance, sound clips, and artistic installations were three mediums that were always mandatory.

Rows - The rows display the different artistic mediums used in each case case study, differentiating ABT cases selected in interviews (in purple) and those selected in articles (in black). Looking at the table row by row allows us to see:

- which art forms were used in a specific case study;
- the range and amount of art forms used in ABT cases.

Some ABT cases only included one artistic medium (e.g., "Sound of Sustainability" with the mandatory creation of sound clips) whilst others mention the use of up to five mediums (Heinrichs, 2021). This was the case for the class "Environmental Education" where students could use any art medium for the assignment, such as artefacts, creative writing, poetry, video, and music (Ison & Bramwell-Lalor, 2023).

Looking by case study, we can see that the range of art forms were either mandatory or optional, there is only one example that indicates one optional and one mandatory art medium: the course "Sustainability Analytics and Visualisation," where cartoon-like drawings were included in the lecture slides (optional) and where students had to design a poster throughout the course and as a final assignment (mandatory). All other cases either require a specific medium or leave all the options open.

Results from the empirical data on IE education context

Drawing and graphic design were the two most used artistic mediums in ABT cases from IE, both mentioned in three cases out of eight. In terms of most used art form, visual arts are the most frequently employed, followed by literary arts, then audiovisual/multimedia, and finally performance arts. Several mediums were not mentioned in the IE cases: photography, dance, sound clips, music, artistic installations.

Results from the systematic review on SHE context

For the ABT cases in SHE, the most used artistic medium was video, with five mentions across 14 cases. This was followed by graphic design which was used in three cases. Overall, all mediums were mentioned in at least one case.

4.2. Reported benefits

This section presents the results from coding the benefits of the use of art and art-based practices in sustainability higher education. **Table 12** displays the list of benefits collected in the literature and in the interviews. Here the documents are referred to as either from "IE interviews" (referring

to the empirical data collected from IE educators and students), or from "SHE articles" (referring to the data collected from the systematic literature review). For this section, frequencies are calculated over the total number of articles and interviews analysed (n = 25), rather than by number of ABT cases. This is because, although not all sources included a concrete instance of art integration in sustainability education, all participants were able to articulate perceived benefits based on their perspectives or experiences outside the pedagogical context. A total of 26 benefits have been identified from the articles and interviews.

Table 12. List and frequencies of benefits linked to ABT mentioned in the SHE and the IE contexts.

Benefits	Frequencies	
	IE interviews (n=14)	SHE articles (n=11)
Acquired new artistic skills	1	1
Broadening perspectives	9	3
Community building	3	2
Empowerment	5	2
Encourage change in (sustainable) behaviour	0	1
Enhanced collaboration	4	2
Enjoyable/fun	6	1
Emotional outlet	4	2
Freedom of expression	2	2
Increased student engagement	6	4
Less (time) pressure	4	2
Making concepts/problems more concrete	7	3
Medium for call to action	0	1
More memorable	7	1
New knowledge on roles of art	0	2
New solution options	5	5
New understanding of sustainability challenges	5	5
Outreach to wider audiences	7	0
Overcome language barrier	3	0
Raise awareness on sustainability issues	2	1
Recycling/upcycling waste	1	1
Socio-cultural grounding	0	1
Stimulate creativity	4	5
Stimulate critical thinking	2	3
Stronger connection to nature	1	1
Visualise future scenarios	5	0

Results from the empirical data on IE education context

'Broadening perspectives' was the most mentioned benefit in IE cases, with nine participants suggesting it. It was mentioned in relation to including and understanding other students'

perspectives: “And I think this may be a good way also within our education to see each other's views more and to see where we're coming from” [Stu 6] and “[art] is much more open to interpretation, which can encourage and bring out more perspectives” [Stu 1], but also in relation to other stakeholders when analysing a sustainability problem: “so I think it has been very helpful to understand other perspectives and it should be used like this I think” [Stu 5] and that it can “encourage them to think about what will be the arguments of the opposite side” [Edu 7].

‘Making problems/issues more concrete’ was also mentioned frequently, in half the cases, and by both educators and students: “And then this sort of artistic formats are actually ways of making it more concrete” [Edu 7] and “I think sometimes these big systems out there to visualise yes, you can sort of do it in LCA, but you can be more concrete than that. And this is where stop motion or other forms of animation can do that, we don't just have to rely on the very formal softwares” [Edu 5].

Two other benefits were mentioned by seven cases: the fact that art makes things ‘more memorable’ and that it helps to ‘outreach to wider audiences’. These two benefits have in common that only one (or no) case from the articles on SHE mentions them, although they are quite frequent in the interviews. For the former benefit, Stu 3 says: “if you engage in the topic in a more practical way, then it really helps you to remember it”. As for the second one, Stu 2 mentioned the fact that art could help in reaching out to wider audiences, especially outside of academia because “while we try to communicate our ideas to general public, where words can be a kind of barrier because of the jargon that we use, maybe [art] opens up ways in which we can communicate non verbally without using jargon”.

Four benefits were not mentioned in the IE cases: ‘encourage change in (sustainable) behaviour’; ‘medium for call to action’; ‘new knowledge on roles of art’; and ‘socio-cultural grounding’.

Results from the systematic review on SHE context

The frequency of benefits mentioned in SHE cases is quite spread out, with the highest mentions of a benefit being five mentions, representing only a little more than a third of cases. On the one hand, three benefits were mentioned in five cases: ‘new solutions options’, ‘new understanding of sustainability challenges’, and ‘stimulate creativity’. On the other hand, three benefits were not

mentioned in the articles: ‘outreach to wider audiences’; ‘overcome language barrier’; and ‘visualise future scenarios’.

The benefit ‘new solution options’ was mentioned equally frequently by articles and by interview participants. For the “Workshop on emergence”, the authors described the integration of ABT methods as catalysts of “crazy and unrealistic ideas [that] catapult the student far beyond the learned structures and paths of scientific methods and create a different starting point for solution-finding” (Heinrich & Kørnøv, 2022, p. 16). The benefit ‘new understanding of sustainability challenges’ was expressed as art enhancing students’ “environmental understanding” (Ison, 2023, p. 976), or their ability to “discern key issues” (Bertaux & Skeirik, 2018, p. 16). Finally, art ‘stimulates creativity’ as “artistic work engages the imagination” (Bertaux & Skeirik, 2018, p. 16), or, as observed in Huang (2024), students’ “scientific creativity performance was better than before participating” (p. 1202).

4.3. Reported challenges

Similarly to the reported benefits, the reported challenges are displayed, with their frequencies over the total number of documents, in **Table 13**.

Table 13. List and frequencies of challenges linked to the use of art and art-based practices in sustainability higher education mentioned in articles and interviews. The frequencies are calculated over the total number of articles (n=11) and interviews (n=14) and not over the total number of ABT cases.

Challenges	Targeting	Frequencies	
		IE interviews (n=14)	SHE articles (n=11)
Administrative burden	Educators	2	1
Afraid of making mistakes	Students	6	0
Art not fit for certain classes	Educators / Students	3	0
Art seen as not serious	Educators / Students	6	1
Assessment criteria of art content	Educators	4	1
Balancing artistic and scientific components	Educators	3	1
Feeling uncomfortable	Students	1	1
Funding required for activities	Educators	1	1
Lack of expertise	Educators	4	3
Limited time of the course	Educators / Students	3	2
Low professor interest	Educators	3	0
Low student interest	Students	4	0
Separation between teachers and students	Educators / Students	0	1
Tension between artistic/scientific thinking	Students	2	1
Time needed to restructure course	Educators	3	0

The qualitative content analysis and the inductive coding process revealed 15 challenges raised in the peer-reviewed literature and by interview participants. Of these challenges, six target educators (e.g., administrative burden, assessment criteria of art content, low professor interest), four concern students (e.g., afraid of making mistakes, feeling uncomfortable), and five affect both educators and students (e.g., limited time of course, art seen as not serious). The two most mentioned challenges were 'art seen as not serious,' and 'lack of expertise,' mentioned by 7 analysed documents, affecting both educators and students. The challenge 'afraid of making mistakes' was the third most pointed out challenge, mentioned in 6 documents. The three least mentioned challenges overall were 'separation between teachers and students' (1 mention), 'feeling uncomfortable' (2 mentions), and 'funding required for activities' (2 mentions).

‘Lack of expertise’ was mentioned almost equally frequently across articles and interviews. This challenge relates to either the educators’ or the students’ lack of technical skills or knowledge in artistic activities. There are two aspects to this challenge, the first aspect relates, on the implementation side, the educators’ lack of expertise, both in artistic skills: “I think that indeed the main issue was that we couldn't do it ourselves in that quality” [Edu 2] and linked to the knowledge of the field in general “This reductionist predisposition made it difficult to present course materials in a manner that accurately reflected a field of study as fluid and dynamic as the arts” (Inwood and Taylor, 2012). This can also manifest itself by having interests and skills in one artistic medium but not others, as expressed by Edu 4: “In [my course], I see way more options to do it through storytelling than through visual media, but that might also just be a factor of the fact that I'm more narrative than visual oriented.” On the students’ side, this challenge is linked to the challenge ‘afraid of making mistakes’ and to the broader fear of judgment: “they are maybe not that much in touch with art or creativity, so they might be scared to express themselves because they don't know how to do it” [Stu 1].

Results from the empirical data collection on IE education context

Following the same trend as for the benefits, the challenges retrieved from the empirical data collection on IE were overall more frequently mentioned, with a range of zero to six mentions per challenge.

The challenge ‘art seen as not serious’ was mentioned in six cases from the IE context. It was expressed relating to different scales (e.g., in the classroom, in the wider scientific community). For instance, Stu 6 explained: “[Engineering students] might feel like things that are outside of learning about engineering are a bit stupid or unnecessary”, also highlighted by Edu 1: “And they think, well, this is such nonsense. It's because I'm not learning about models. I'm not learning about scientific methods and those kinds of things”. Stu 3 mentioned this issue on a wider scale: “In the general scientific community, I think art is not seen as something serious.”

The challenge ‘afraid of making mistakes’ was suggested in 6 of the interviews, but not in articles. Specifically, four educators and two students mentioned this challenge. Edu 7 explained, linking this challenge to engineers in general: “An engineer, if you ask them to make an art project, they are not going to go there because they don't know what it is, you know, and when you're unsure, you become a bit scared and you don't want to go there.” Edu 4 related this challenge

particularly to undergraduate students, emphasising that: “They're quite scared of doing something wrong, definitely. And they don't trust their own judgment that much yet.”

Results from the systematic review on SHE context

For the articles, the number of mentions per challenge ranged from zero to three mentions. Most challenges mentioned in the literature were only mentioned once throughout the articles. The most mentioned challenge was ‘lack of expertise’. Five challenges were not mentioned at all in the articles, namely ‘afraid of making mistakes’, ‘art not fit for certain classes', ‘low professor interest’, ‘low student interest ', and ‘time needed to restructure course’.

4.4. Contribution to Sustainability Key Competencies

Focusing on the benefits identified in the documents led to a tentative categorisation of the benefits according to the key competencies displayed in **Table 14.** One benefit could be linked to several key competencies. These are exemplified with direct quotes from articles and interviews in **Table C1** in **Appendix C**.

As can be seen in **Table 14,** most of the benefits recorded from the analyses of documents (that is, peer reviewed articles on SHE and interview transcripts from IE students and educators) could be linked to Brundiers et al. (2021)’s seven sustainability key competencies, excluding the integrated problem-solving competency. The competencies that most benefits could potentially contribute to was the intrapersonal competency (10 benefits), followed by the interpersonal competency (7 benefits). Future-thinking competency was only linked with two benefits. Finally, five benefits were not considered as contributors to any key competency, namely ‘acquired new artistic skills’, ‘more memorable’, ‘new knowledge on roles of art’, ‘stimulate creativity’, and ‘stimulate critical thinking’.

Table 14. Overview of key competencies from Brundiers et al. (2021) and benefits that contribute to their achievement. Because of the overarching nature of the integrated problem-solving competency, no benefits are associated with that key competency.

Benefits	Sustainability key competencies							
	Systems-thinking	Values-thinking	Strategic-thinking	Futures-thinking	Intrapersonal	Interpersonal	Implementation	Integrated problem solving
Acquired new artistic skills								
Broadening perspectives	X	X				X		
Community building		X	X			X		
Emotional outlet					X			
Empowerment					X			
Encourage change in (sustainable) behaviour					X			
Enhanced collaboration			X	X		X		
Enjoyable/fun					X			
Freedom of expression			X		X			
Increased student engagement					X			
Less (time) pressure					X			
Making concepts/problems more concrete	X				X	X		
Medium for call to action		X						
More memorable								
New knowledge on roles of art								
New solution options			X				X	
New understanding of sustainability challenges	X	X						
Outreach to wider audiences						X		
Overcome language barrier						X		
Raise awareness on sustainability issues						X		
Recycling/upcycling waste		X						
Socio-cultural grounding					X			
Stimulate creativity								
Stimulate critical thinking								
Stronger connection to nature		X						
Visualise future scenarios			X	X	X			

Chapter 5. Discussion

5.1. Interpretation of results

This section builds on the results from the literature review ABT cases in SHE and cases in IE education from the empirical data to compare and discuss trends and outcomes.

5.1.1. Current art practices in sustainability higher education

Through the systematic analysis of 22 ABT cases collected in a literature review and interviews with educators and students, this research has recorded the current use of ABT practices in sustainability higher education to answer SRQ1: "**Why and how has art been used in sustainability higher education?"**

The dimension **(1) student population** demonstrated that ABT practices were introduced to a range of sustainability undergraduate and graduate programs including engineering (civil engineering and management), natural sciences (environmental science, biochemistry), socio-cultural (cultural studies, pedagogical studies, management), and inter/multidisciplinary programs (IE, urban studies, art and technology, environmental economics). This was of course due to the methods used for this research, specifically the inclusion criteria for the literature review and the interview participants, which deliberately included students in sustainability higher education programs. The group sizes for the ABT cases ranged from 15 to 51 students, with most cases falling in the range of 20 to 30 students per class. For several ABT cases, authors or interview participants mentioned that the group size was an important factor for the facilitation of the course or workshop: "Last, but not least, the size of the seminar matters. In our seminar, 25 students participated, this was already a lot" (Heinrichs, 2021, p. 7). They specifically link this dimension with the need for class discussions and reflections during and following the use of creative practices in class, due to the complexity associated with the learning of new methods. Not included as a case study, Jónsdóttir (2017) mentions two aspects relating to group sizes, after the author herself was requested to include a maximum of 12 students in her class. On the one hand, students preferred smaller groups where they could build trust more easily, since a lot of the exercises were based on personal experiences. On the other hand, larger groups would allow a higher diversity of

perspectives and opportunities for exchange. While smaller groups may allow for more trust and deeper reflection, the cases reviewed show that ABT practices are not limited to such settings. They can also be adapted to larger class sizes. This demonstrates that ABT can be implemented across a range of educational contexts in sustainability.

Linking the **(2) teaching team** dimension with the **(4) integration type** and **(6) artistic medium** also informs us on some trends: when the teaching teams were a collaboration between a sustainability educator and an artist, they were also whole classes or workshops dedicated to integrating art and sciences, and most often the artistic medium was unique and mandatory. This is the case for the three ABT cases from Heinrichs (2021) ("Sound of Sustainability", Bureau of expertise and "Sustainability, Politics, Everyday Life"), the "Dancing Waters" workshop in Bruzzone & Stridsberg (2023), and the "Introduction to Environmental Art Education" course in Inwood & Taylor (2012). An exception is the course "Sustainability Analytics and Visualisations" where the educator for this course, although from an interdisciplinary field, was not working in collaboration with an artist. The choice of medium is often aligned with the teaching team's expertise, which can also be deduced from the recurrence of the challenge "lack of expertise." The analysis revealed that videos was the most frequently used **(6) artistic medium,** and was both made mandatory by educators as it was chosen voluntarily by students. Other artistic mediums, such as performance, sound clips, artistic installations, and dance were less frequent and most of the time facilitated by artists in these fields.

In terms of **(3) student participation**, the results showed that 15 ABT cases from both literature and empirical data included ABT practices where students were actively involved in the creative process. On that aspect, the literature suggests several benefits to including art in a participatory manner. Participatory art enhances student agency, making the learning experience more meaningful and empowering (Wall et al., 2019). As expressed by Inwood & Taylor (2012), with participatory art practices, students gain a "sense of ownership over the material and ultimately the environmental issue being addressed" (Inwood & Taylor, 2012, p. 119). In addition, art creation is also an outlet for students to deal with difficult dilemmas, which is also a benefit cited by some student interview participants (Stoll, 2022; [Stu 6]). However, that is not to say that non-participatory art and artistic works used as a support for class discussion are not valuable. These representations can already help students grasp different perspectives on sustainability issues (Molderez & Ceulemans, 2018).

Finally, the **(5) purposes for ABT** practices can be compared to those in Heras (2022). The purposes of "mapping the system" and "visualising future scenarios" resonate with Heras' (2022) motivation of *increasing knowledge and awareness of sustainability challenges*, as this motivation, compared to the other two, is focused on the knowledge and content acquisition surrounding sustainability issues. Moreover, purposes such as "increase connection to nature", "encourage sense of place", and "identify and express emotions" align with Heras' (2022) motivation *amplifying personal and affective connections with the environment*. However, identified purposes such as "encourage discussion", "generate ideas", and "communicate results" are less explicitly present in Heras (2022) categories. These relate more to the specific context of this study, which is the use of art and art-based practices in sustainability higher education, where research and academic goals guide the educational objectives of both educators and students.

When comparing the results in frequencies between the purposes mentioned in IE cases versus those mentioned in SHE cases, four purposes were not mentioned in interviews on IE cases, namely: 'broadening perspectives', 'raise environmental awareness', 'encourage sense of place', and 'increase connection to nature'. The four purposes are more closely associated with emotions. The purpose 'raise environmental awareness' was not prominent in the empirical data, likely because, with one exception, the IE sample did not involve mixed cohorts, and students enrolled in these courses already possessed a high level of environmental awareness. In contrast, in the literature-based cases, 'raise environmental awareness' emerged as the second most frequently mentioned purpose, likely for the reason outlined above. For the other three purposes not mentioned in IE cases, this may be because IE curricula tend to be more technically oriented, with a focus on quantitative methods and systems modelling, which may leave less space for activities designed to evoke emotional connections. From this comparison, it can be deduced that the more affective dimensions of ABT are not yet fully integrated into IE education, or at least were not evident in this sample of educators and students.

5.1.2. Reported benefits

The second SRQ that this study aimed to answer was: **"What are the potential benefits of including art practices for sustainability higher education?"**

The potential benefits of integrating art and art-based practices in sustainability higher education were obtained by qualitative content analysis of ABT cases from the peer-reviewed

literature and from conducting interviews. A total of 26 benefits were identified from this process. The wide range of benefits aligns with the outcomes of Heras (2022)'s findings, who had identified purposes and motivations of art practices to affect 1) one's knowledge and awareness of sustainability issues and socioecological dynamics, 2) their personal connections with the environment, and 3) the empowering effect of art and increase in learners' agency. The benefits identified in the current study also manifest across multiple scales, ranging from the individual level (e.g., stronger connection to nature, acquired new artistic skills), to the classroom and institutional level (e.g., increased student engagement, enhanced collaboration), and extending to the broader community and even global contexts (e.g., outreach to wider audience, community building).

The three benefits of 'outreach to wider audiences', 'overcome language barrier', and 'visualise future scenarios' were not mentioned in the ABT cases from SHE articles. This is interesting as, while IE is often perceived as a more technical branch of sustainability research, the findings show a strong emphasis on communicating results to wider audiences, which is also reflected in the identified purposes (purpose 'communication of results' which was mostly mentioned in interviews). Another notable focus within the IE sample was the use of art to visualise future scenarios, a benefit absent from the SHE literature, suggesting a distinctive alignment with the field's systems-thinking and modelling traditions. The benefit *overcome language barrier* was mentioned three times in the interviews—by two students and one educator—but never in the articles reviewed. This gap may partly reflect the lack of direct student perspectives in much of the literature, where benefits are often reported from the educator's viewpoint.

There were few mentions of using art as an emotional outlet related to feelings of eco-anxiety and other emotions linked to climate change consequences. However, the literature suggests that art is a valuable emotional outlet for anxiety concerning sustainability issues (Horvath et al., 2023). In this study, one example came from the course "Transdisciplinary Approaches for Sustainability Innovation," where students participated in a body mapping and check-in wheel exercise designed to externalise emotional responses through symbolic expression: "each of us had a little drawing of ourselves and we had to illustrate how we felt using different symbols" [Stu 6]. These types of practices resonate with calls in the literature to address the affective dimensions of climate education, which can often contribute to emotional

detachment, pessimism, and even paralysis when presented in overly abstract or technical terms (Ojala, 2012; Mitchell & Laycock, 2019). Although affective benefits are not included in academic grading criteria and were not widespread in this study's sample, the few instances identified suggest potential for arts-based approaches to support emotional support and literacy in sustainability education.

Overall, the results for the SHE context were quite equally spread out, whereas the benefits mentioned in interviews with IE educators and students were mostly concerning: 1) the outreach to broader publics ('overcome language barrier', 'outreach to wider audience'), outside of the IE domain, which can only be done through understanding other perspectives ('broadening perspectives'); and 2) the direct benefits for students in the classroom, relating to student's ability to engage ('student engagement'), learn, and remember teachings on sustainability challenges (making 'more memorable' their 'new understanding of sustainability challenges').

5.1.3. Reported challenges

This study answered the following sub research question **"What are the potential challenges of including art practices for sustainability higher education?**" by identifying recurring themes in the interviews and selected articles.

The literature (11 articles) reported fewer challenges compared to the interview participants. Although the frequencies cannot be directly compared, as they are not normalised and serve only as an indication, this discrepancy suggests the presence of reporting bias. This aligns with Dawson & Dawson (2018) discussion of "sharing successes and hiding failures" in learning and teaching research, which highlights how published studies may underreport difficulties relative to firsthand accounts. However, several articles included in this study still reported several challenges linked to the authors' experience in integrating ABT, and provided recommendations on how to overcome them (Heinrichs, 2021; Bruzzone & Stridsberg, 2023; Heinrich & Kørnov, 2022).

The overarching challenge to the integration of art in SHE concerns a cultural aspect raised by the literature on ABT, which is the tension between scientific and artistic methodologies and thinking. Art-based and affective approaches in sustainability higher education remain undervalued in many academic settings, and rational, measurable, and outcome-driven knowledge continues to dominate (Acevedo et al., 2022; Heinrich & Kørnov, 2022; Jónsdóttir, 2017). This is

reflected in the challenge identified in this study: the perception that ‘art is seen as not serious’ or lacks academic legitimacy. As Acevedo et al. (2022) argue, practices linked to personal, emotional, or care-based domains are often dismissed as not rigorous enough. Similarly, Höpfl (2014) critiques the patriarchal obsession with quantification and classification, which marginalises maternal values such as care, creativity, and affect. These structural biases help explain why several participants in this study expressed concern about using art-based methods in engineering courses, or why art was more accepted when framed as a communication tool rather than a method of inquiry.

This tension is emphasised in the concerns educators expressed about openly pursuing affective or reflective outcomes in their courses. As noted by Shephard (2008), many instructors worry that addressing values and emotions might be perceived as manipulative or too subjective to be considered valid learning objectives. In this study, benefits such as ‘emotional outlet,’ ‘freedom of expression,’ and ‘identifying and expressing emotions’ were reported, yet these were also accompanied by challenges such as ‘feeling uncomfortable’, ‘afraid of making mistakes’, or ‘lack of clear assessment criteria’. Thus, these results suggest that even though affective learning outcomes are valued by educators and students, institutional norms (such as emphasis on short-term assessments, or disciplinary boundaries) limit their integration. Heinrichs (2021) also addresses this tension, particularly concerning the mismatch between the art practices in class with the “traditional scientific evaluation criteria” that is widespread in Western higher education institutions (p. 12). The author argues for a scientific-artistic framework that would help solve this challenge.

The findings also point to ways to challenge these norms, particularly through the inclusion of indigenous artistic and pedagogical practices. Benefits such as “raising environmental awareness,” “socio-cultural grounding,” and “increased connection to nature” suggest that art can facilitate more embodied and place-based forms of learning. They correspond to aspects of indigenous knowledge systems which use artistic expression for knowledge production and intergenerational transmission (Archibald, 2008). It is important to question the definition of legitimate knowledge, and the idea that art is not serious in comparison to other more traditional alternatives used in Western contexts (Acevedo et al., 2022).

5.1.4. Linking art-based teaching to sustainability key competencies

Finally, this study aimed to answer the question **"Which sustainability key competencies could be achieved through the addition of art-practices to sustainability higher education?"**

The difficulty of linking art-based practices to the achievement of sustainability key competencies lies in the fact that very few articles or educators and students know about key competencies frameworks. Indeed, only one article included in the review explicitly mentioned the framework of sustainability key competencies by Wiek et al. (2011) (Heinrichs, 2021). In addition, outside this literature review, few peer-reviewed articles explicitly link the benefits of art-based approaches in sustainability education with a framework of sustainability key competencies (Heras, 2022; Molderez & Ceulemans, 2018). In her study Heras (2022), found that arts-based pedagogies most strongly supported the development of the intrapersonal, normative, and collaboration competencies, while competencies such as anticipatory and strategic were less frequently addressed. Similarly, this study's findings also demonstrate a strong presence of intrapersonal (e.g., 'emotional outlet' or 'increased connection to nature'), interpersonal (e.g., 'enhanced collaboration', 'overcome language barrier')and values-thinking (e.g., 'raise awareness on sustainability issues', 'socio-cultural grounding') key competencies. However, the most mentioned benefits, especially in the interviews, are related to practical learning benefits in the classroom, not directly linked to specific key competencies. For instance, 'making concepts/problems more concrete' was often mentioned in interviews, but is a means to broader benefits, such as 'mapping the system' or ''new understanding of sustainability challenges'. Moreover, similarly to Heras (2022), this study revealed weaker links between art integration and systems-thinking, and futures-thinking, strategic thinking, and implementation key competencies. Five identified benefits can contribute to the implementation key competency. These benefits might contribute to the implementation key competency by the fact that using art can enhance the "collective ability to realise a planned solution toward a sustainability-informed vision", but it does not address the two other aspects of this competency, namely, "to monitor and evaluate the realisation process, and to address emerging challenges (adjustments)" (Brundiers et al., 2021, p. 21).

Heras (2022) suggests that a new competency emerges from the analysis of the roles and benefits of art in sustainability education. The author calls this competency "sensing the world," where art allows one to slow down and connect more purposefully with oneself and the

environment around them. Similarly, Heinrichs (2021) also argues for the addition of a new sustainability key competency "*which could be called sensory-aesthetic competence".*

5.2. Reflection on methods

Because of the exploratory nature of this research, as well as the limited time and resources available for it, the study bears several limitations.

5.2.1 Systematic literature review on SHE context

First, this study's systematic literature review only included peer-reviewed scientific literature, and did not look at grey literature. However, more ABT cases of art-practices might be available in grey literature, for instance in blogs or conference workshop summaries. An example of that is the blog shared by one interviewee [Stu 6] about a class they attended. The blog gives great examples of how creative art practices have been and can be included in sustainability higher education, however, it is only available in grey literature. Further research could and should include such sources for a more holistic understanding of the integration of art and art practices in sustainability higher education programs.

5.2.2. Empirical data collection

Second, regarding the empirical data collection, another sampling method could have been applied. The current research used a mix of convenience and purposive sampling to select interview participants, and only through conducting the interviews were the ABT cases (the unit of analysis) selected. An alternative approach could have started by selecting all mandatory courses from European IE programs and then contacting the corresponding professors, rather than first selecting participants and subsequently identifying ABT cases. This method might have included a more systematically representative set of ABT interventions. The process could have followed a different sampling method displayed in **Figure 7.**

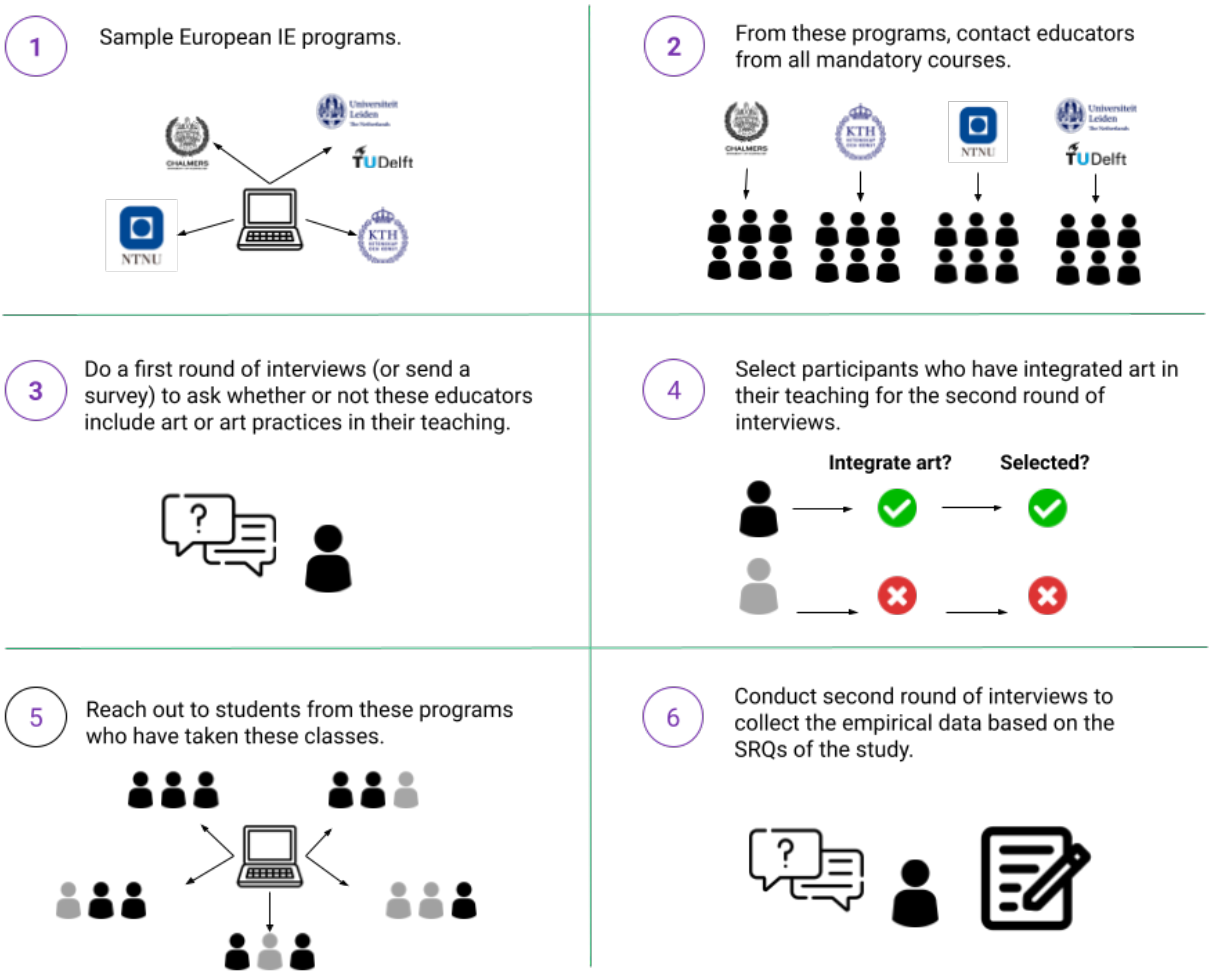

Figure 7. Alternative empirical data collection sampling methodology.

In addition, the interview participants only include staff and students from northern european universities, based on convenience sampling. The study focuses on a specific educational context and may not be directly generalisable to all settings or populations (Jónsdóttir, 2017). The study's reliance on qualitative data can introduce subjectivity in interpretation. Indeed, a main limitation to this study was that a single person was responsible for the coding, where literature on qualitative research methods advises the cross-checking of codes with other researchers, and with considerable time between coding rounds (Stevens, 2023). This was not done due to time limitations.

Finally, and importantly, Brundiers et al. (2021) point to some limitations in their study, particularly the lack of inclusion of indigenous perspectives in this framework of key competencies, and in general the missing perspectives of non-Western voices. This is also the case

for this study which has only included interview participants from northern european universities, with mostly european participants. It is important to recognise that the integration of art in sustainability education is not a novel or exclusively Western innovation. Non-Western and Indigenous educational traditions have long used artistic practices as central modes of teaching, learning, and knowledge transmission (Bequette, 2007; Acevedo et al., 2022). Storytelling, song, dance, visual symbolism, and ritual are deeply embedded in many Indigenous and local epistemologies, to convey information and strengthen community bonds, transmit values, and connect people to place and environment (Archibald, 2008; Whiteye, 2009). These practices emphasise relationality, spirituality, and cultural continuity. This is also present in Ison (2021), whose case study, based in Jamaica, illustrates how art-based activities grounded in local cultural expressions supported what the current study identifies as "socio-cultural grounding." In that context, creative practices were not only pedagogically effective but also allowed students to reaffirm their connection to their community and cultural identity. This reminds us that so-called transformative or innovative approaches in sustainability education are often similar to or based on long-standing practices in non-Western contexts (Andreotti et al., 2016).

Chapter 6. Conclusion and further research

This study aimed to answer the main research question: "**What are the benefits and challenges of integrating art-based teaching in sustainability higher education to support the achievement of key competencies?**" To do so, four sub-research questions were developed, and answered through qualitative content analysis of selected 11 peer-reviewed articles through a systematic literature review, and through an empirical data collection of 14 interviews with educators and students from four northern European universities.

The first aim was to identify how and why ABT practices were integrated in sustainability higher education. The analysis provided an overview and range of practices in ABT cases by categorising several contextual factors and ABT intervention dimensions. ABT was applied across different disciplines, and group size influenced levels of trust and reflection among students. Courses co-taught with artists tended to support deeper integration and more diverse artistic media, while limited expertise often constrained choices. Most cases involved active student participation, which enhanced engagement and ownership, though non-participatory uses also added value. The purposes identified such as mapping systems, expressing emotion, and generating ideas align with existing literature but also reflect the academic and research-oriented goals specific to higher education settings.

The second and third aims were focused on identifying potential benefits and barriers to the integration of ABT in sustainability higher education. This study identified 26 benefits. The broad range and diversity of benefits, which aligns with the literature on the topic, demonstrates the potential of ABT for sustainability education. However, 15 challenges were also mentioned in articles and interviews. These challenges can influence the integration of art on both a pedagogical level and an implementation level. In addition, the challenges identified raised questions relating to cultural educational paradigms in Western higher education institutions.

Furthermore, a link between the benefits collected and Brundiers et al. (2021) framework of sustainability key competencies was drawn. The findings from this study were also compared with those from Heras (2022), which had found supporting evidence that art was especially beneficial in terms of intrapersonal, interpersonal, and normative competencies. Our findings confirm that trend, and also highlighted the potential of ABT and art-based practices for

anticipatory and systems-thinking competencies, especially mentioned by educators from the IE field. However, through the analysis of this study's selected ABT cases, there was no particular evidence pointing at the fact that ABT would help achieve the implementation competency.

Future research could expand this work by including interviewees from a wider range of disciplinary backgrounds, cultural contexts, and educational systems, and in particular from non-Western or Indigenous traditions, where art has long been central to knowledge transmission. In addition, future studies could investigate the long-term impacts of art-based interventions on student engagement, behavior change, and professional practice. Another area of investigation would be to look at how institutional structures, for example curriculum design, assessment systems, and educator training, can be adapted to support the integration of art within higher education.

References

Acevedo, B., Malevicius, R., Fadli, H., & Lamberti, C. (2022). Aesthetics and education for sustainability. *Culture and Organization*, *28*(3–4), 263–278. https://doi.org/10.1080/14759551.2022.2028147

Andreotti, V. de O., Geo-JaJa, M. A., & Majhanovich, S. (2016). Education, Knowledge and the Righting of Wrongs. In *Effects of Globalization on Education Systems and Development* (pp. 131–141). SensePublishers. https://doi.org/10.1007/978-94-6300-729-0_8

Angeler, D. G. (2016). Viewing biodiversity through the lens of science…and art! *SpringerPlus*, *5*(1), 1174. https://doi.org/10.1186/s40064-016-2831-z

Archibald, J. (2008). *Indigenous storywork: Educating the heart, mind, body, and spirit*. UBC Press.

ATLAS.ti Scientific Software Development GmbH. (2023). ATLAS.ti Mac (version 23.2.1) [Qualitative data analysis software]. https://atlasti.com

Bennetts, C. (2003). The impact of transformational learning on individuals, families and communities. International Journal of Lifelong Education, 22(5), 457–480.

Bequette, J. W. (2007). Traditional Arts Knowledge, Traditional Ecological Lore: The Intersection of Art Education and Environmental Education. *Studies in Art Education*, *48*(4), 360–374. https://doi.org/10.1080/00393541.2007.11650114

Bringezu, S. (2017). Industrial ecology and Material Flow Analysis: Basic Concepts, Policy Relevance and Some Case Studies. In S. Erkman (Ed.), *Perspectives on Industrial Ecology* (First edition.). Greenleaf Pub. https://doi.org/10.4324/97813512820

Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., Dripps, W., Habron, G., Harré, N., Jarchow, M., Losch, K., Michel, J., Mochizuki, Y., Rieckmann, M., Parnell, R., Walker, P., & Zint, M. (2021). Key competencies in sustainability in higher education—toward an agreed-upon reference framework. *Sustainability Science*, *16*(1), 13–29. https://doi.org/10.1007/s11625-020-00838-2

Brundiers, K., Wiek, A., & Redman, C. L. (2010). Real-world learning opportunities in sustainability: From classroom into the real world. *International Journal of Sustainability in Higher Education*, *11*(4), 308–324. https://doi.org/10.1108/14676371011077540

Bruzzone, S., & Stridsberg, H. (2023). Dancing Urban Waters. A Posthuman Feminist Perspective on Arts-Based Practice for Sustainable Education. In M. Cozza & S. Gherardi (Eds.), *The Posthumanist Epistemology of Practice Theory* (pp. 123–150). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-42276-8_5

Buckler, C., & Creech, H. (2014). *Shaping the Future We Want: UN Decade of Education for Sustainable Development (2005-2014) : Final Report*. UNESCO.

Davis, S., & Tarrant, M. (2014). Environmentalism, stories and science: Exploring applied theatre processes for sustainability education. *Research in Drama Education: The Journal of Applied Theatre and Performance*, *19*(2), 190–194. https://doi.org/10.1080/13569783.2014.895613

Dawson, P., & Dawson, S. L. (2018). Sharing successes and hiding failures: 'Reporting bias' in learning and teaching research. *Studies in Higher Education*, *43*(8), 1405–1416. https://doi.org/10.1080/03075079.2016.1258052

Delahaye, R., Bogaart, P., Couzy, P., & Schoenaker, N. (2020). *Analyzing and Visualizing Material Flows within the Circular Economy*.

Eckelman, M. J., & Laboy, M. M. (2020). LCAart: Communicating industrial ecology at a human scale. *Journal of Industrial Ecology*, *24*(4), 736–747. https://doi.org/10.1111/jiec.12978

Finlayson, A., Markewitz, K., & Frayret, J.-M. (2014). Postsecondary Education in Industrial Ecology Across the World. *Journal of Industrial Ecology*, *18*(6), 931–941. https://doi.org/10.1111/jiec.12215

Flowers, M., & Barrett, M. J. (2014). Animism, Creativity, and a Tree: Shifting into Nature Connection through Attention to Subtle Energies and Contemplative Art Practice.

Franco, I., Saito, O., Vaughter, P., Whereat, J., Kanie, N., & Takemoto, K. (2019). Higher education for sustainable development: Actioning the global goals in policy, curriculum and practice. *Sustainability Science*, *14*(6), 1621–1642. https://doi.org/10.1007/s11625-018-0628-4

George, J. (2024). Elephants, Ecological Grief, and Art Therapy. *Art Therapy*, *41*(3), 118–127. https://doi-org.tudelft.idm.oclc.org/10.1080/07421656.2024.2339014

Haley, D., Vargas, V. R., & Ferrulli, P. (2017). Weaving the Filigree: Paradoxes, Opposites and Diversity for Participatory, Emergent Arts and Design Curricula on Sustainable Development. In W. Leal Filho, L. Brandli, P. Castro, & J. Newman (Eds.), *Handbook*

of Theory and Practice of Sustainable Development in Higher Education (pp. 281–296). Springer International Publishing. https://doi.org/10.1007/978-3-319-47868-5_18

Heinrich, F., & Kørnøv, L. (2022). Art and higher education for environmental sustainability: A matter of emergence? *International Journal of Sustainability in Higher Education*, *23*(3), 728–747. https://doi.org/10.1108/IJSHE-01-2021-0012

Heinrichs, H. (2021). Teaching Sustainable Development in a Sensory and Artful Way—Concepts, Methods, and Examples. *Sustainability*, *13*(24), 13619. https://doi.org/10.3390/su132413619

Heras, M. (2022). Art and Connectedness within Sustainability: Educating Through Aesthetic Pedagogies. In *Competences in Education for Sustainable Development* (pp. 145–157). Springer, Cham. https://doi.org/10.1007/978-3-030-91055-6_18

Heras, M., Galafassi, D., Oteros-Rozas, E., Ravera, F., Berraquero-Díaz, L., & Ruiz-Mallén, I. (2021). Realising potentials for arts-based sustainability science. *Sustainability Science*, *16*(6), 1875–1889. https://doi.org/10.1007/s11625-021-01002-0

Hirt, J., Nordhausen, T., Fuerst, T., Ewald, H., & Appenzeller-Herzog, C. (2024). Guidance on terminology, application, and reporting of citation searching: The TARCiS statement. *BMJ*, *385*, e078384. https://doi.org/10.1136/bmj-2023-078384

Horvath, A.-S., Löchtefeld, M., Heinrich, F., & Bemman, B. (2023). STEAM Matters for Sustainability: 10 Years of Art and Technology Student Research on Sustainability Through Problem-based Learning. *Journal of Problem Based Learning in Higher Education*, *11*(2), 1–33. https://doi.org/10.54337/ojs.jpblhe.v11i2.7768

Horvath, S.-M., Payerhofer, U., Wals, A., & Gratzer, G. (2025). The art of arts-based interventions in transdisciplinary sustainability research. *Sustainability Science*, *20*(2), 547–563. https://doi.org/10.1007/s11625-024-01614-2

Hossan, D., Dato' Mansor, Z., & Jaharuddin, N. S. (2023). Research Population and Sampling in Quantitative Study. *International Journal of Business and Technopreneurship (IJBT)*, *13*(3), 209–222. https://doi.org/10.58915/ijbt.v13i3.263

Hume, T., & Barry, J. (2015). Environmental Education and Education for Sustainable Development. In *International Encyclopedia of the Social & Behavioral Sciences* (Second Edition, Vol. 7, pp. 733–739). Elsevier Ltd. https://doi.org/10.1016/B978-0-08-097086-8.91081-X

International Society for Industrial Ecology - IESE. (2025). What is industrial ecology? Is4ie.org. https://is4ie.org/about/what-is-industrial-ecology

Jónsdóttir, Á. B. (2017). *Artistic actions for sustainability: Potential of art in education for sustainability*. Lapin Yliopisto.

Kaufmann, D. B., Palawat, K., Sandhaus, S., Buxner, S., McMahon, E., & Ramírez-Andreotta, M. D. (2023). Communicating environmental data through art: the role of emotion and memory in evoking environmental action. *Humanities & Social Sciences Communications*, *10*(1), 940–14. https://doi.org/10.1057/s41599-023-02459-3

Leal Filho, W., Sima, M., Sharifi, A., Luetz, J. M., Salvia, A. L., Mifsud, M., Olooto, F. M., Djekic, I., Anholon, R., Rampasso, I., Kwabena Donkor, F., Dinis, M. A. P., Klavins, M., Finnveden, G., Chari, M. M., Molthan-Hill, P., Mifsud, A., Sen, S. K., & Lokupitiya, E. (2021). Handling climate change education at universities: An overview. *Environmental Sciences Europe*, *33*(1), 109. https://doi.org/10.1186/s12302-021-00552-5

Lotz-Sisitka, H., Wals, A. E., Kronlid, D., & McGarry, D. (2015). Transformative, transgressive social learning: Rethinking higher education pedagogy in times of systemic global dysfunction. *Current Opinion in Environmental Sustainability*, *16*, 73–80. https://doi.org/10.1016/j.cosust.2015.07.018

Malytska, O., Patron, I., Chabanenko, N., Shvets, O., Polishchuk, A., & Martyniv, L. (2022). Development of Art Education as a Basis for Sustainable Development of Society. *Postmodern Openings*, *13*(1 Sup1), 247–265. https://doi.org/10.18662/po/13.1Sup1/425

Mitchell, T., & Laycock, H. (2019). The affective gap: Climate change, emotions, and the promise of aesthetics. *Journal of Aesthetic Education, 53*(4), 41–56. https://doi.org/10.5406/jaesteduc.53.4.0041

Molderez, I., & Ceulemans, K. (2018). The power of art to foster systems thinking, one of the key competencies of education for sustainable development. *Journal of Cleaner Production*, *186*, 758–770. https://doi.org/10.1016/j.jclepro.2018.03.120

Molthan-Hill, P., Blaj-Ward, L., Mbah, M. F., & Ledley, T. S. (2021). Climate Change Education at Universities: Relevance and Strategies for Every Discipline. In M. Lackner, B. Sajjadi, & W.-Y. Chen (Eds), *Handbook of Climate Change Mitigation and Adaptation* (pp. 1–64). Springer New York. https://doi.org/10.1007/978-1-4614-6431-0_153-1

Monroe, M. C., Plate, R. R., Oxarart, A., Bowers, A., & Chaves, W. A. (2019). Identifying effective climate change education strategies: A systematic review of the research. *Environmental Education Research*, *25*(6), 791–812. https://doi.org/10.1080/13504622.2017.1360842

Nazir, J., Pedretti, E., Wallace, J., Montemurro, D., & Inwood, H. (2009). Climate Change and Sustainable Development: The Response from Education The Canadian Perspective. In *International Alliance of Leading Educational Institutions*. https://hilaryinwood.ca/pdfs/research/ESD%20in%20Canada%202009.pdf

O'Neill, S., & Nicholson-Cole, S. (2009). Fear Won't Do It: Promoting Positive Engagement With Climate Change Through Visual and Iconic Representations. *Science Communication*, *30*(3), 355–379. https://doi.org/10.1177/1075547008329201

Ojala, M. (2012). Hope and climate change: The importance of hope for environmental engagement among young people. *Environmental Education Research, 18*(5), 625–642. https://doi.org/10.1080/13504622.2011.637157

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., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, n71. https://doi.org/10.1136/bmj.n71

Papavasileiou, V., Nikolaou, E., Andreadakis, N., Xanthacou, Y., & Kaila, M. (2020). The role of Art in Environmental Education. In *IJAEDU-International E-Journal of Advances in Education: Vol. VI*. http://ijaedu.ocerintjournals.org

Redman, A., & Wiek, A. (2021). Competencies for Advancing Transformations Towards Sustainability. *Frontiers in Education*, *6*. https://doi.org/10.3389/feduc.2021.785163

Rieckmann, M. (2012). Future-oriented higher education: Which key competencies should be fostered through university teaching and learning? *Futures*, *44*(2), 127–135. https://doi.org/10.1016/j.futures.2011.09.005

Rieckmann, M. (2018). Learning to transform the world: Key competences in Education for Sustainable Development. In *Issues and Trends in Education for Sustainable Development*; Leicht, A., Heiss, J., Byun, W.J., Eds.; UNESCO: Paris, France.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169. https://doi.org/10.1007/BF01405730

Scarff Seatter, C., & Ceulemans, K. (2017). Teaching Sustainability in Higher Education: Pedagogical Styles that Make a Difference. *Canadian Journal of Higher Education*, *47*(2), 47–70. https://doi.org/10.47678/cjhe.v47i2.186284

Shackleton, S., Bezerra, J. C., Cockburn, J., Reed, M. G., & Abu, R. (2021). Interviews and surveys. In The Routledge handbook of research methods for social-ecological systems (pp. 107-118). Routledge.

Stevens, P. A. J. (2023). Chapter - 8 Qualitative Content Analysis: A Practical Introduction. In *Qualitative Data Analysis*. SAGE Publications, Limited.

United Nations. (2025). *The 17 sustainable development goals*. United Nations. https://sdgs.un.org/goals

University of Toronto. (2024). *Defining environmental and sustainability education* . Utoronto.ca. https://www.oise.utoronto.ca/scan/defining-environmental-sustainability-education-0

Wall, T., Österlind, E., Fries, J. (2019). Art-Based Teaching on Sustainable Development. In: Leal Filho, W. (eds) Encyclopedia of Sustainability in Higher Education. Springer, Cham. https://doi.org/10.1007/978-3-030-11352-0_195

Wardle, A. (2025). Nature-based art therapy: supporting children's emotional regulation and responses to the climate crisis. International Journal of Art Therapy, 30(1), 28–35. https://doi-org.tudelft.idm.oclc.org/10.1080/17454832.2024.2382955

Weiss, M., & Barth, M. (2019). Global research landscape of sustainability curricula implementation in higher education. *International Journal of Sustainability in Higher Education*, *20*(4), 570–589. https://doi.org/10.1108/IJSHE-10-2018-0190

Whiteye, P. (2009). [Rev. of *Jo-ann Archibald / Q'um Q'um Xiiem. . Indigenous Storywork: Educating the Heart, Mind, Body, and Spirit*]. *Canadian Journal of Education*, *32*(1), 188.

Wholey, J. S. (Ed.). (2010). *Handbook of practical program evaluation* (3rd ed). Jossey-Bass.

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, *6*(2), 203–218. https://doi.org/10.1007/s11625-011-0132-6

APPENDIX A

Interview guides used to collect qualitative data from educators and students.

1. Educators interview guide

Introduction

Thank you for participating in this interview. The purpose of this conversation is to explore how art-based approaches may or may not be integrated into Industrial Ecology education and how you perceive their role. Your answers will be kept confidential and anonymised. There are no right or wrong answers—please share your honest thoughts and experiences.

Teaching Background

Q0.a. What courses or types of content do you currently teach in the Industrial Ecology programme?

Q0.b. How would you describe your general approach to teaching?

Experience with Art Integration

Q1. Have you ever integrated art-based practices or creative elements in your teaching?

If the answer is yes

Q2. Was it a one-time experiment or a recurring approach?

Q3. What was the purpose?

Q4. What kind of art practices were used?

Q5. What was the **aim** or **learning objective**?

If the answer is no

Q6. Why not?

Perceived Benefits

Q7. In your experience or opinion, what are/would be the main benefits of integrating art-based approaches into Industrial Ecology education?

Perceived Challenges

Q8. What challenges have you encountered—or anticipate encountering—when using or planning to use art practices in your teaching?

Closing

Thank you very much for your time. If you have any concerns or questions, I have written down my contact information as well as my supervisor's in the consent form that you had to sign before the interview.

2. Student interview guide

Introduction

Thank you for participating in this interview. The purpose of this conversation is to explore how art-based approaches may or may not be integrated into Industrial Ecology education and how you perceive their role. Your answers will be kept confidential and anonymised. There are no right or wrong answers—please share your honest thoughts and experiences.

Background Information

Q0.a. What year of the Industrial Ecology programme are you currently in?

Q0.b. What was your academic or professional background before joining the programme?

Experience with Art Practices

Q1. Have you ever experienced any integration of art or creative practices in your lectures, projects, or assignments in this programme?

Q2. Was it a one-time experiment or a recurring approach?

Q3. What was the purpose?

Q4. What kind of art practices were used?

Q5. In terms of methodological approach, did you use artistic methods only or integrated with scientific methods?

Q6. What was the **aim** or **learning objective**?

Perceived Benefits

Q7. Based on your experience or expectations, what do you think are the potential benefits of integrating art-based approaches into Industrial Ecology education?

If a participant is struggling to list benefits, then suggest: understanding complex topics, encouraging collaboration, expressing emotions, etc.

Perceived Challenges

Q8. What do you see as possible challenges or limitations of using art approaches in this field?

Closing

Thank you very much for your time. If you have any concerns or questions, I have written down my contact information as well as my supervisor's in the consent form that you had to sign before the interview.