Design thinking as digital transformative pedagogy in higher sustainability education: Cases from Japan and Germany

Sadaf Taimur [*], Motoharu Onuki

Graduate Program in Sustainability Science – Global Leadership Initiative (GPSS-GLI), University of Tokyo, Kashiwa, Japan

A R T I C L E   I N F O

A B S T R A C T

There is an increasing emphasis on using transformative learning approach through pedagogies to make Higher Sustainability Education (HSE) more effective. The study explores how Design Thinking (DT) as a pedagogy can be conducive to transformative learning in the digital settings, in HSE, by incorporating the critical components of the Digital Transformative Pedagogy (DTP) framework. The study describes the design and implementation of two courses from universities in Japan and Germany and captures the participants' perspectives on their experiences. The research findings emphasize that DT pedagogy successfully incorporates all the components of the DTP framework in both cases (hybrid and digital settings) to set up learning processes and environment favorable for transformative learning experiences. The research can offer concrete practice, pathways, and lessons for curriculum development to bring transformative learning into digital teaching practice in HSE.

1. Introduction

Humans' unsustainable practices have led to wicked social and ecological challenges such as climate change, social inequalities, and toxic pollution. Sustainability as a field and movement started as a response to deal with these wicked sustainability challenges (Blackstock & Carter, 2007; Burns, 2016; Grunwald, 2004; Talwar et al., 2011). Since the 1970s, education has been linked to change and the need to achieve sustainability at a global level (Sterling, 2004). UNESCO defined Sustainability Education (SE), also known as Education for Sustainable Development (ESD), as education that intends to empower students to make informed decisions and responsible actions to ensure economic feasibility, environmental integrity, and just society while respecting cultural diversity – for the present and future generations (UNESCO, 2017). Research supports that SE is needed at all levels, however, those who have access to higher education (and commonly take decision making and leadership roles in the communities) should be well-versed with sustainability to deal with complex sustainability challenges in local and global communities (Burns, 2009). In higher education settings, SE aims to educate leaders who can go out in society and contribute towards achieving sustainability (Onuki & Mino, 2009). SE in higher education settings or higher sustainability education (HSE) can play a crucial role in developing leaders who can deal with complex, pressing, and wicked sustainability challenges.

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* Corresponding author.
  E-mail address: sadaf.taimur@s.k.u-tokyo.ac.jp (S. Taimur).

1.1. Higher sustainability education & transformative learning

The interdisciplinary nature of HSE demands change as moving towards sustainability is not possible with the current (transmissive) approaches (Moore, 2005), as these approaches do not equip students to deal with complex and profoundly challenging sustainability issues (Sterling, 2010). It is time to change the educational culture to enable the transition towards a sustainable world by shifting the ways of thinking and learning to be more connective, systemic, holistic, and ecological (Sterling, 2001). This shift requires moving from a teacher-centered transmissive approach to a learner-centered transformative approach.

Mezirow, one of the most significant thought leaders in the field of transformative learning, defined transformative learning as:

"*a process by which we transform our taken-for-granted frames of reference…to make them more inclusive, discriminating, open, emotionally capable of change, and reflective so that they may generate beliefs and options that will prove more true or justified to guide action*" (Mezirow, 2000, p. 7–8).

Transformative learning is not about adding to an individual's existing knowledge base but is more about being aware of one's own and others' perspectives, subsequently, evaluating the relevance of these perspectives (critically) to interpret (Mezirow, 2000). Mezirow (1990) writes:

"*…it is not so much what happens to people but how they interpret and explain what happens to them that determines their actions, their hopes, their contentment, and emotional well-being, and their performance.*" (pp. xiii).

Transformative learning is developmental to some extent, but it is more about understanding learning as a process of using a prior interpretation to construe a revised or new interpretation of the meaning of one's experience to guide future action. In HSE, transformative learning transforms learners' perspectives (worldviews) and values to embrace sustainability as a new paradigm through which they can view the world and make a difference (Burns, 2009, 2015). Encouraging transformative learning in HSE will lead to reorienting societies towards sustainability. Universities have immense potential to lead in questioning paradigms, challenging status-quos, and practicing new thinking, teaching, learning, living. Therefore, there is a need to shift teaching in HSE to bring transformative learning into practice.

1.2. Transformative pedagogy for transformative learning in higher sustainability education

There are different aspects of transformative learning, but all of them share an emphasis on learning processes and environment (pedagogy) focusing on critical reflection, experience, and discourse (Mezirow, 2003; Taimur & Onuki, 2020; Taylor, 2007). Therefore, it is crucial to focus on pedagogy to embed transformative learning in HSE (Taimur, 2020; Taimur & Onuki, 2020) and move from transmissive pedagogy to transformative pedagogy (Burns, 2009). Transformative pedagogy is defined as a pedagogy that can construct learning environments and processes that expose learners to transformative learning experiences; this allows students to examine their assumptions critically, grapple with social issues, and engage in social action (Meyers, 2008). This kind of pedagogy is usually structured around action-oriented projects and problem-oriented approaches (Kitano, 1997; Meyers, 2008; Nielsen, 2020); hence, problem-based learning can provide such experiences. There are studies showcasing practices for implementing problem-oriented, project-based learning in HSE and their importance (e.g., Birdman et al., 2021; Caniglia et al., 2018), but the potential of problem-based learning is yet not realized due to the limited emphasis on its use in universities (Leal Filho et al., 2018).

1.3. Design thinking as transformative pedagogy in higher sustainability education

Design Thinking (DT) is defined as a human-centered problem-solving approach to deal with "wicked" challenges (Buchanan, 1992; Dam & Siang, 2018; Thienen et al., 2014). DT has its roots in architecture and industrial design practice (Lawson, 2006) but the shift of its application from traditional spaces of product, interior, and graphic design to services, innovation strategies and interaction design has created an impetus for DT as an approach to solve wicked challenges in multiple domains (Buchanan, 1992). DT can be utilized as a pedagogy (Luka, 2014), to implement the problem-based learning approach in higher education settings (Acharya et al., 2021). It is different from other problem-based learning approaches because: it allows participants to frame problems instead of working on pre-determined problems, and the iterative stages of DT pedagogy are supported by explicit strategies (tools) (Melles et al., 2015).

DT can be applied to the problems which are ill-defined, human-centered, uncertain (dynamic), not understandable with the help of available data (Liedtka, 2020, University of Virginia, 2020), require creative re-definition (Buchanan, 1992), and involve conflicting interests (Wrigley & Straker, 2015). Sustainability challenges, being wicked, align with the characteristics of the problems to which DT can be applied. Correspondingly, human-centered design is socially situated in values and sense-making; a design thinker being a transformative learner, can draw from diverse perspectives, see beyond others, and imagine innovative solutions that are better than existing choices (Avsec & Ferk Savec, 2021). DT can promote transformative learning by (a) focusing on values; (b) being multidimensional and multidisciplinary; (c) producing clear resolves for multiple stakeholders and produce learning outcomes that can address these resolves; (d) creating space for enabling interdisciplinary reflective discourse, (e) promoting social critique and stakeholders engagement to strengthen the relationship between learning experiences, curriculum, needs of students and other stakeholders, and (f) encouraging risk-taking and exploration (Avsec & Ferk Savec, 2021; Benson & Dresdow, 2014). Hence, DT as a transformative pedagogy can be used in HSE as effective way to nurture sustainability leaders – by empowering learners to make a difference in society and equip them to deal with complex challenges (Munyai, 2016). When DT is applied as a pedagogy in HSE, it

allows learners (in a diverse team) to frame a sustainability challenge in a particular context (area/region/community) and then work on innovative solutions or response ideas to deal with the framed sustainability challenge. DT has been explored in sustainability and HSE; there is a need to explore DT as a transformative pedagogy in HSE.

Over time various models of DT have been developed based on Simon's (1969) DT process. The most notable among them, for application in education (Melles et al., 2015), is created by the Institute of Design at Stanford D-School (Plattner, 2010, 2009). This transferable approach emerges from the human-centered design principles and entails five iterative stages: empathize, define, ideate, prototype, test. In the current research, we considered five-staged DT pedagogy (Plattner, 2010), where the last stage, i.e., test, was converted to present, keeping in mind that DT was being used as a pedagogy in an educational context. Brown (2009) referred to the implementation (test) stage as the development of ideas into a concrete, well-conceived action plan; translating this to the education settings entails communicating what is designed to enhance understanding and engaging multiple stakeholders (Benson & Dresdow, 2014). Fig. 1 explains the stages of DT pedagogy diagrammatically. DT is not linear and is an iterative pedagogy where learners can move back and forth between all the stages of DT.

Amid the COVID-19 pandemic, many countries instituted temporary school and university closures starting in March 2020 (García-Morales et al., 2021). As an emergency response, many universities transitioned from face-to-face to digital or online learning systems (Marinoni et al., 2020; Murphy, 2020). Online teaching and learning became a new normal created by COVID-19 disruptions and made higher education more transmissive. According to Carolan et al. (2020), the immediate response of many higher education institutions has been shifting from face-to-face teaching to synchronous online lectures or asynchronous lecture capture or podcasts. The impact of the pandemic will bring an era of radical technological transformation, and there will be an acceleration in the digitalization of higher education across the globe (Krishnamurthy, 2020). Universities need to seriously rethink and redesign their educational approach to face this new era of technological transformation. This is a crucial time to explore DT as digital transformative pedagogy (DTP) in HSE to bring transformative learning into practice and make HSE effective. In this research, DTP is referred to as a transformative pedagogy in digital settings which can set up learning processes and environment to encourage transformative learning in the digital settings.

2. Design thinking as digital transformative pedagogy - conceptual framework

DT as DTP is defined as DT as a transformative pedagogy in digital settings which can create learning processes and environment conducive to transformative learning in digital settings. The research employs the Digital Transformative Pedagogy (DTP) framework, built on Burn's model of sustainability pedagogy (Burns, 2009, 2011), and extended to teaching and learning in digital settings. The framework explains how DT as DTP can bring various framework elements together in HSE to bring transformative learning into digital teaching and learning practice. Through DTP, HSE (even in digital settings) can train and empower learners to deal with complex sustainability problems and make a difference that contributes to the sustainability of the places and communities. Fig. 2 represents the visual depiction of the framework and its components. The DTP framework is comprised of six components:
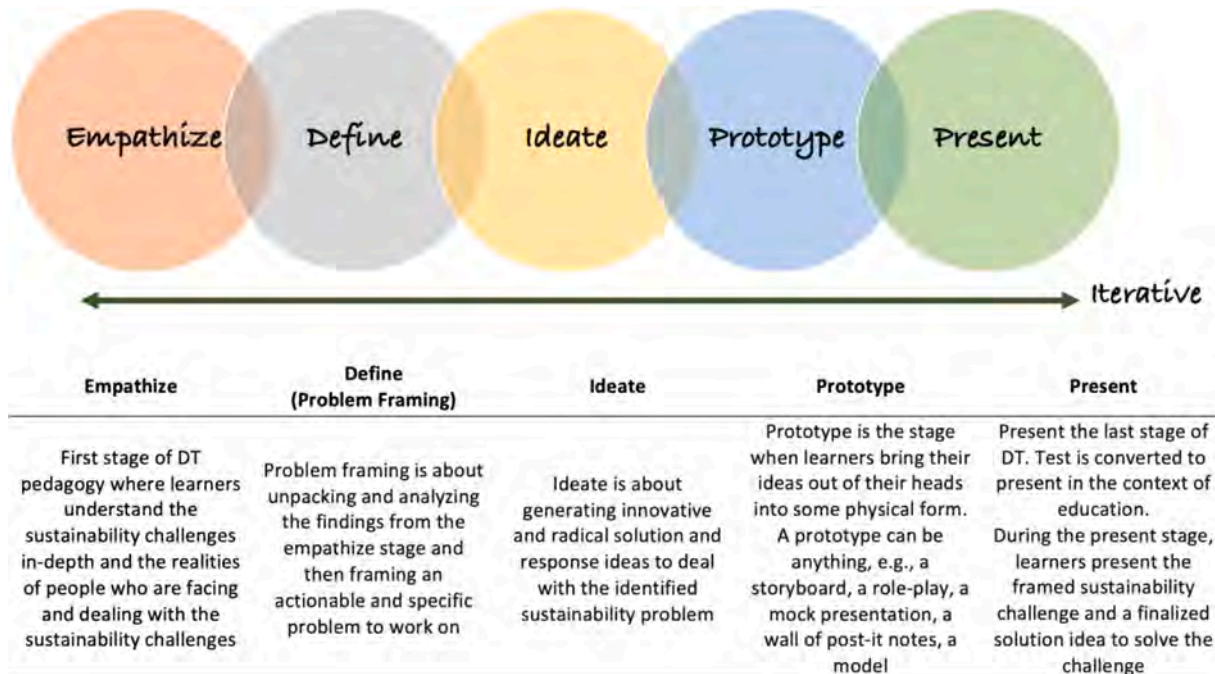

Empathize	Define (Problem Framing)	Ideate	Prototype	Present
First stage of DT pedagogy where learners understand the sustainability challenges in-depth and the realities of people who are facing and dealing with the sustainability challenges	Problem framing is about unpacking and analyzing the findings from the empathize stage and then framing an actionable and specific problem to work on	Ideate is about generating innovative and radical solution and response ideas to deal with the identified sustainability problem	Prototype is the stage when learners bring their ideas out of their heads into some physical form. A prototype can be anything, e.g., a storyboard, a role-play, a mock presentation, a wall of post-it notes, a model	Present the last stage of DT. Test is converted to present in the context of education. During the present stage, learners present the framed sustainability challenge and a finalized solution idea to solve the challenge

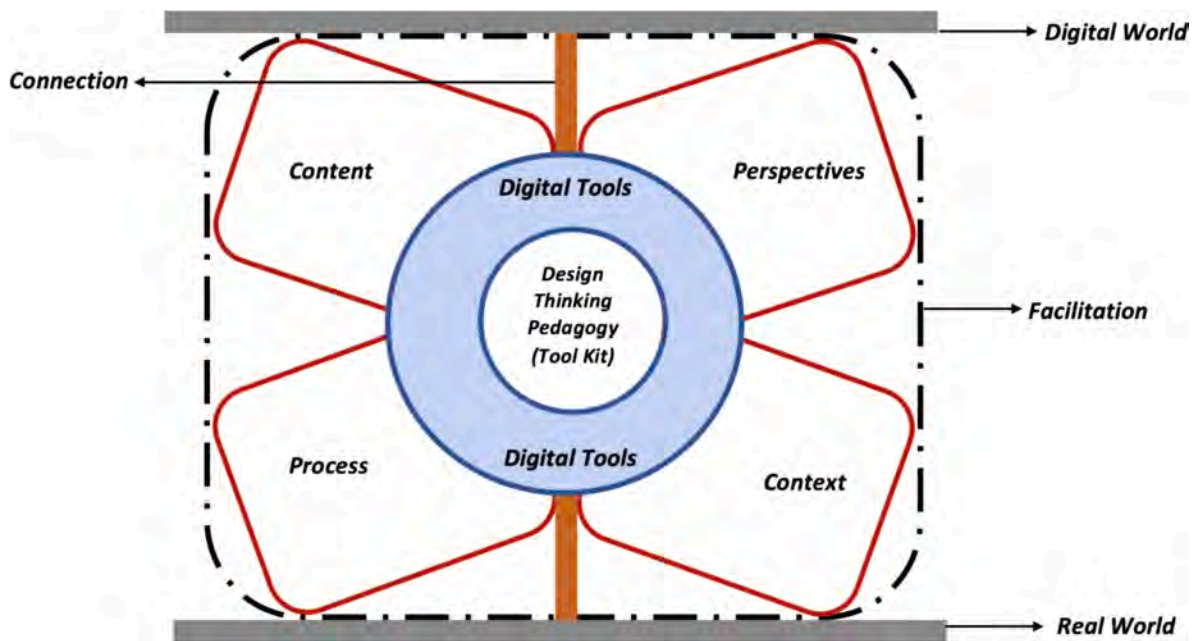**Fig. 1.** Stages of Design Thinking Pedagogy (Adapted from Plattner, 2010).

Fig. 2. Design Thinking Pedagogy aligned to Digital Transformative Pedagogy (DTP) framework.

- Content – course should be designed with the sustainability theme;
- Perspective – diverse perspectives should be provided to the learners;
- Process – opportunities for direct participation and experiential learning should be provided to the learners;
- Context – learning should be attached to a place/region/community;
- Digital tools – appropriate digital tools are selected to meet the needs of the other components of the framework;
- Facilitation – teaching team should facilitate the learning.

The detailed explanation of all the components of the framework are provided in Table 1.

2.1. Program design (design thinking toolkit)

The learning program design, using DT as DTP, incorporates designing the methods with the set of guidelines to support the learning and action of learners during each stage of DT. These methodological guidelines to support the learning and action of learners during each stage of DT are termed DT tools (adapted from Plattner 2010). DT tools are compiled together along with the plan for each learning session in the form of a tool kit for implementing DT pedagogy in the digital settings, e.g., DT toolkit compiled by 2012 (Riverdale Country School., & IDEO 2011) and Stanford Institute of Design (Plattner, 2010). Digital tools must be selected and prepared while designing the DT toolkit for the learning program. Ecological design (Hemenway, 2000), as suggested by Burns (2011), can be used to design the DT toolkit. The five basic, iterative steps of ecological design are observation, visioning, planning, development, and Implementation. Details of ecological design can be seen in Table 2, with corresponding considerations and actions for each step. DT toolkit, designed based on the ecological design, can bring together all the components of the DTP framework.

2.2. The connection between digital and real world

The DTP framework suggests that the digital learning space requires a connection with the real world to ensure authentic learning experiences. DT will connect the digital world with the real world by bringing together all the components of the DTP framework together and providing an authentic learning experience to the learners. Laiken (2005) (in Herrington and Herrington, 2005) posits that authentic learning experiences lead to transformative learning because they force the congruence between beliefs and behaviors, enabling learners to strive continuously to achieve this congruence. Authentic learning experiences, being transformative, will ensure that learners are better equipped to solve real-world sustainability problems even outside their classrooms. Herrington et al. (2003) postulate that cognitive authenticity rather than physical authenticity is crucial for authentic learning experiences. Therefore, authenticity is not constrained to real-world situations and practice. Authentic learning experiences can be provided in digital settings by incorporating nine critical characteristics of the authentic learning environment (Herrington, 2006; Herrington & Herrington, 2005, Herrington et al., 2014), also listed in Table 2. DT as DTP incorporates all the critical characteristics of an authentic learning environment to connect the digital world with the real world by bringing together six components of the DTP framework (see Table 3). Table 3 shows how characteristics of an authentic learning environment can be incorporated in the program design (DT toolkit) by the

Table 1
Explanation of the six components of the DTP framework.

Component of DTP framework	Explanation
Content	DT as a DTP enable learners to recognize patterns, relationships, and dynamics by getting a non-fragmented understanding of the complex and multi-dimensional sustainability challenges. According to Burns (2009, 2011), the content shall be structured around a sustainability theme within a course to ensure effective multidisciplinary teaching. For example, urban sustainability has been used as a theme in a university course by Li et al. (2018), where DT is used to develop students' skills to understand, formulate, and solve urban sustainability problems from multiple dimensions in consultation with local experts, scholars, and non-governmental organizations. DT as a DTP uses sustainability theme (e.g., biodiversity, livable cities, health), allowing learners to explore the selected theme in-depth from multiple dimensions in consultation with stakeholders, frame a challenge linked to the sustainability theme, and then develop solutions or responses to deal with the framed sustainability challenge. Although content is an integral part of the DTP, it is one component of the framework. Providing knowledge about sustainability is not enough; therefore, content must be combined with the other components of the framework by providing learners with diverse perspectives and beliefs on sustainability content (perspectives), skills and values to deal with the sustainability content (process and context), coaching support, and digital tools to explore the sustainability content (facilitation and digital tools). The dynamic nature of sustainability challenges also requires learners to learn new content related to sustainability in order to connect new knowledge to the previous knowledge and then construct new meaning in relationship with other learners through discourse and reflection.
Perspective	The second component of the DTP framework is providing learners with diverse perspectives to give them an opportunity to think critically about dominant power relationships, practices, and paradigms. Learners need diverse perspectives to view and understand sustainability issues in multiple ways – to reflect on the causes of unsustainable practices and highlight the usually invisible social, ecological, physical, and economic impacts (Cortese, 2005). Critiquing and questioning the underlying cultural assumptions and dominant (economic and power) relationships that create harmful and unsustainable practices are crucial to be included in HSE (Burn, 2009, 2011). For example, if the theme of the course is climate change, it would be essential to discuss and reflect on dominant patterns and practices, e.g., production and consumption, coal-burning, driving cars, and using fossil fuels that contribute to climate change. These dominant practices, e.g., driving cars, while being ecologically damaging, need cultural acceptance for their prevalence and participation from most people. Learning about climate change will require understanding the underlying causes and assumptions of people driving cars, such as focusing on convenience, economic growth, and maintaining social inequities. Learning about climate change will also involve considering perspectives alternative to the dominant practices, e.g., listening to a community member who uses a bicycle for commuting or talking to a social entrepreneur running a local bike-sharing business. Sustainability challenges, being complex, cannot be understood or framed from a single perspective. Herrington (2006) and Herrington et al. (2014) also emphasized exploring multiple perspectives to equip learners to solve complex real-world challenges in the digital learning environment. DT as DTP incorporates diverse perspectives to ensure a holistic understanding of the sustainability issue. Learners can encounter diverse perspectives by reading material with multiple perspectives, working in diverse teams, speaking to, or listening to different stakeholders (even from under-represented and marginalized groups), and visiting the specific sites/area/region/region/community. Gathering diverse perspectives create an interpersonal dynamic essential to engage in experiential learning (process).
Process	The process as a component signifies the opportunities for learners for direct (active) participation and experiential learning. While adopting a sustainability theme and providing diverse perspectives, DT as DTP focuses on making a difference (change for sustainability) which requires engagement with oneself, others, and the environment (places) (Burns, 2011). Through active, experiential, and participatory learning, DT can enhance the sense of civic responsibility and desire to work for sustainability among learners. According to Kaza (1999), learners in higher education usually experience denial, despair, and self-absorption when exposed to the facts regarding socio-ecological challenges, which is not enough to empower or inspire them to act for social change. Therefore, it is vital to allow learners to engage in the challenges through active participation. Active participation includes allowing learners to participate in sustainable practices in the communities, in their own lives, and on the campuses (Cortese, 2005). This kind of active participation can be facilitated by engaging learners in creative thinking and problem-solving in small groups regarding sustainable practices. Burns (2009) posits that service-learning, due to its experiential and participatory nature, is focused on leadership development and civic engagement, and therefore, it is an exceptional application of sustainability (transformative) pedagogy. DT as DTP integrates service-learning by engaging learners in community service where they understand and define a sustainability challenge in a particular community(place) and then develop ideas to deal with that challenge. This experience develops both learners and the service site (community/place). DT may enhance the sense of civic responsibility among learners, a natural extension of their relationships within the communities or places where they are engaged during service learning. The process component of the framework involving the active participation of the learners is connected to the next component of the framework, i.e., context, because active participation for making a difference means that DTP must be situated in a context where learners can engage in service-learning.
Context	Context is vital for DTP to enhance learners' connection with and understanding of the geographical place and community. DT as DTP must be rooted in the place where learning occurs, e.g., during the implementation of DT pedagogy, learners frame a sustainability challenge in a particular geographical place and then formulate solution ideas for the framed challenge incorporating the needs of the respective context. Situating learning in the context while implementing DT pedagogy will help in providing a base to experience other components of the DTP framework. Orr (1992) stated: "places are laboratories of diversity and complexity, mixing social functions and natural processes" (p. 129). Embedding learning in an authentic context can motivate learners and create a complex learning environment that can be explored at length (Herrington, 2006; Herrington et al., 2014); as an outcome learners can learn to be an inhabitant of the place, and their mutual relationship with the place can strengthen (Burns, 2009). Although, it is challenging to set the context in digital settings, DT as DTP can situate learning in the context through field visits (virtual and personal), interviews with stakeholders involved, and information (literature) on the existing sustainability practices/projects. Situating the learning in the context can enable learners to overcome the gap between the digital world and the real world.
Digital Tools	Selection of appropriate digital tools is necessary for utilizing DT as DTP. Appropriate digital tools are the ones (programs, online platforms, websites, or online resources) that can support all the other components of the DTP framework (content, perspective, process, context, and facilitation), and these tools fit the needs of the context they are applied in. For example, 3D virtual tools might be helpful to set up the context for learners in one higher education institution, but they may not be applied to another institution due to the lack of accessibility to the 3D virtual tools. In that case, the YouTube website or pre-recorded videos can set up the context.

Table 1 (*continued*)

Component of DTP framework	Explanation
	Therefore, the disgression of which tools are appropriate in a particular context is left to the individuals (educators) designing the program using DT as DTP. They will decide which digital tools can support the five other components of the DTP framework in their context. Some examples of the frequently used digital teaching tools include Zoom, MS Teams, Google Meets and Classrooms, Miro boards, Mural, Google forms, Dropbox, YouTube, Kahoot, FexiQuiz (Meena & Rumao, 2021; Reimers et al., 2020). Digital teaching tools contribute to effective learning and learners' presence in the classroom (Gregory & Bannister-Tyrrell, 2017) by translating the virtual activities into the impression of real people/world (Dixson, 2010). In the virtual settings, learners are separated from each other and the real world, learning in the digital world; hence, authenticity is lacking. DT as DTP connects the digital world with the real people and the real world by utilizing appropriate digital teaching tools. Technological tools can support authentic learning to bridge the gap between transmissive instructions and real-life application of the knowledge (Herrington & Kervin, 2007). Brickell and Herrington (2006) explained an example of "The Geography Challenge," which utilized the digital tools for setting up an authentic problem-based learning environment. The challenge used the site of Olympic 2000, Sydney Olympic Park, as a context while keeping biodiversity and resource conservation as the sustainability theme (content). Web resources and excursions were used as technological tools to set up an authentic context by realistically presenting the learning scenario using animation, images, and sound. Digital tools are an essential and central component of the DTP framework to bring transformative learning into practice in HSE, using DT.
Facilitation	To implement DT as DTP, educators must be facilitators of learning rather than being disseminators of knowledge (instructors). The role of educators/teachers is to support generation of the new paradigms by helping learners elaborate, transform, and create their meaning schemes through reflection on their content, the process through which they have learned, and their premises (Mezirow, 1978, 1991). The facilitation by educators enables the interaction of all the components of the DTP framework, and it is an essential aspect of teaching practice while implementing DT as a pedagogy. The educators develop trusting and caring relationships with the learners and extend their support when needed to empower learners to experience paradigm shifts. Educators can bring the other components of the DTP framework together with the help of the program design before implementation and through facilitation during the program's implementation. Educators must provide support using appropriate communication technologies to bridge the gap between the real and virtual worlds in a digital learning environment (Collins et al., 1989; Greenfield, 1984). To extend support for bringing authenticity in the learning environment requires educators to take a powerful but different role (Choi & Hannafin, 1995; Herrington, 2006), where the educator interacts with learners at a metacognitive level (Savery & Duffy, 1996). In many universities, the role of the educators is more instructive where they tell learners what they need to do rather than assuming a supporting role (Harley, 1993), and hence, the educators control the learning situation (Berge et al., 2000; Jonassen, 1993) making the learning more transmissive. Educator-controlled learning situations may breach the ethical dimensions of transformative learning and lead to brainwashing or coercion (Taimur & Onuki, 2020). Pluralism of thought should be encouraged through facilitation instead of concealing it with controlled (transmissive) learning situations. Ideally, the facilitator's role description should be outlined and communicated to the learners.

Table 2

Steps of ecological design to build a DT toolkit.

Steps of ecological design	Brief description	Examples of corresponding considerations or actions to build a DT toolkit
Observation	Observing what is available to work with, what are the conditions, and what are the constraints	− What can be the sustainability theme − Which resources are available and can be integrated? − Who are the learners? − What will be the context? (Observing the context if that aligns to the theme and the needs of the course) − What are the strengths and weaknesses of the educator? − How was the program implemented previously?
Visioning	Considering the outcomes and objectives of the course/program	− What will be the learning outcomes and objectives? − Narrowing down the sustainability theme – exploring one theme in depth − How will learners perceive the course? − How to build a relationship between learners and the tone of the program
Planning	Asking, what is needed to implement the ideas (resources/activities/assignments/tools)	− Carving out details e.g., o which community resources will be used? o who will be invited as speakers? o which digital tools will be used and how will they be incorporated in the design? o which DT tools will be used during each stage of DT and how will they be designed
Development	Focusing on how the program design will be implemented and making decisions regarding learning activities and assignments/projects	− Designing the DT toolkit with DT tools, sequence of activities, digital tools being used, and schedules, incorporating all the components of DTP framework − Making decision regarding the assessment − Adapting/designing the digital tools according to the DT toolkit
Implementation	Teaching the course and readjustment based on further observations, visioning, planning, and development to enhance sustainability learning	− Facilitating the program/course − Assessing the toolkit and learners' learning experiences to improve the toolkit further − Making further adjustments in the DT toolkit based on observations

Table 3

Characteristics of Authentic Learning Environment aligned to Program Design (DT toolkit) using Component/s of DTP Framework.

Characteristic/s of Authentic Learning Environment	Program Design (DT toolkit) using Component/s of DTP Framework		Description
• **Authentic context** – (all-embracing context providing a sustained learning environment)	• Context	**Digital Tools**	Learning is embedded/situated in a context. For example, through DT, learners frame a sustainability challenge in a particular geographical area and then attempt to design solutions to deal with that problem. The context is all-embracing and provides a sustained learning environment where learners use the DT tools, practically in the same context.
• **Authentic Activities -** (ill-defined activities and tasks with real-world relevance, performed by the learners) • **Authentic Assessment** – (assessment of learners' performance shall be integrated with the activities)	• Process		• The DT tools (methodological guidelines) for flexible and ill-defined activities for each stage of DT allow learners to practically work with the tools in the real-world context to go through each stage of DT pedagogy. • The progress checks designed for each stage of DT are well integrated with the DT tools provided to the learners and activities performed based on those tools.
• **Access to expert performance and modeling of process** - (to provide students with exposure to the expert performance gives them access to expert thinking and practice) • **Multiple roles and perspectives** - (encouraging learners to explore multiple perspectives and recurrently crisscross the learning environment) • **Collaborative construction of knowledge** – (collaboration with other learners to solve the problem together)	• Perspectives		• Diverse perspectives are incorporated through DT pedagogy, allowing learners to work in diverse teams, organize team-building activities for effective team collaboration, assess team performance (rather than individual performance), speak to or listen to the relevant stakeholders/experts, and digitally visit the area/region/community.
• **Reflection** – (learners shall be provided with opportunities to reflect on their learnings) • **Articulation** – (opportunities for articulation shall be provided to the learners)	• Content • Perspectives • Process • Context • Facilitation		• Reflection and discourse (articulation) are the two most important conditions for transformative learning to occur, and these two characteristics bring together all the six components of the DTP framework. Learners are engaged in reflection and articulation when: (a) they are examining or exploring a particular sustainability theme (content); (b) they are working in diverse teams or talking to experts/stakeholders (perspectives); (c) they are practically working with the DT tools with real-world relevance (process); (d) they are examining a particular sustainability issue in a specific geographical area or understanding and solving the sustainability issue in a particular context (context); (e) they are supported by the teaching team to get involved in articulation and reflection.
• **Coaching & Scaffolding** – (teachers shall take coaching role rather than instructional role)	• Facilitation		• The teaching team takes the role of facilitator rather than an instructor to help learners construct their meanings.

respective component/s of the DTP framework. It can be seen (Table 3) that digital tools are central to connecting the digital world to the real world and bringing authenticity to the learning experiences.

3. Purpose of the research

The purpose of the study is to explore DT as DTP during (a) a hybrid (mix of online and face-to-face) field exercise course for graduate students at the University of Tokyo, Japan; and (b) a complimentary online course for undergraduate students at Leuphana University, Germany. The study describes the design and implementation of the courses mentioned above using DT as DTP. It also captures the participants' perspectives to analyze; if DT as a transformative pedagogy could incorporate the components of the DTP framework and the impact of DT as DTP on participants' perceived learning experiences. The following research questions (RQs) guided this study:

- How can learning programs in HSE be designed and implemented using DT as DTP?
- How does DT as a transformative pedagogy incorporate the components of the DTP framework?
- How do learners in both cases perceive their learning experiences aligned to the DTP framework?

The study is not focused on identifying if transformative learning has occurred or not, but the focus is on exploring if DT as DTP sets up the conditions for transformative learning to occur to inform the curriculum design and learning. The research attempts to contribute to the need for digital transformative pedagogy to prepare HSE for the upcoming technological revolution.

4. Methodology

4.1. Research approach

The current research used the case-study approach to investigate the phenomenon within the context where it occurs (Creswell and Creswell, 2017; Merriam, 1988), and effectively capture contemporary teaching practices in a real life context (Yin, 2009). The research could be conceived as an "instrumental case-study"as described by Stake (1995, 2003). The cases examined a phenomenon (issue), i.e., learning processes and environment set via DT as DTP and corresponding impacts of implementation on perceived learning experiences of the learners. The research develops inspirations to inform the curriculum design and learning in HSE in the digital settings by constructing knowledge on how DT as DTP can be implemented in the HSE and how it can establish processes and environment for transformative learning. Stake (1995, 2003) highlighted that the selected cases should facilitate understanding of the phenomenon/issue under study and maximize what research can learn. Based on this criterion, a field exercise course from the University of Tokyo in Japan and a complimentary course from Leuphana University in Germany were selected as (a) both courses aimed at addressing sustainability challenges in a specific context; (b) both courses are open to students from different academic majors; (c) both courses have utilized digital mode of implementation amid the COVID-19 pandemic. Thus, it became convenient to re-design and implement DT as DTP in both cases and collect data to examine if DT as DTP could incorporate the components of the DTP framework to create enabling environment and processes for the occurrence of transformative learning. Elmassah et al. (2021) also examined the cases of the Leuphana University of Lüneburg and the University of Tokyo to identify the roles and successful techniques of higher education institutions to achieve sustainable development in their respective countries. The two cases are briefly described as follows and in Table 4.

Case-1: Field Exercise Course in Sustainability Science (FESS), University of Tokyo – FESS course at Graduate Program in Sustainability Science-Global Leadership Initiative (GPSS-GLI), the University of Tokyo was selected as a case. GPSS-GLI is an HSE, graduate-level, academic program (Mino et al., 2016) and offers a FESS course for graduate students that takes Kashiwa no ha (region) as the area of investigation interest for participating students. This case was selected to provide insights and understanding on DT as DTP in a graduate-level course in a hybrid setting. Students' perspectives on their experiences during the course, based on six components of the DTP framework, were captured via reflection sheets, observations, and semi-structured interviews with all the participants.

Case-2: Design Thinking for Sustainability (DTS), Complimentary Course – Leuphana University - DTS course, at Leuphana University, Germany, was targeted as a case for the study. Complimentary studies are part of Leuphana's Bachelor's program and are offered to all undergraduate students (Leuphana University, 2021a) to sharpen their skill profile in their field, in another field across disciplines (Adomßent, 2016). Therefore, this case was selected to provide insights and understanding on DT as DTP in an undergraduate-level course in digital settings. Participating students' perspectives were captured, based on the six components of the DTP framework, qualitatively through reflection sheets, observations, final reports, and semi-structured interviews with selected participants.

4.2. Design & implementation of design thinking as digital transformative pedagogy

DT as DTP, incorporating six components of the DTP framework, was used to design and implement the FESS and DTS courses. Both courses were designed by compiling a DT toolkit outlining all the course components using ecological design (Burns, 2011; Hemenway, 2000), with the help of a faculty member from each university. DT toolkit, with all the course components, included an elaborated explanation of the sessions and tools to implement DT as DTP. The tools for each stage of DT were adapted from 2020, 2012, Plattner (2010), Tschimmel et al. (2017), UNLEASH (2019) and tailored to incorporate the components of the DTP framework to be used to meet the objective of the courses (dealing with sustainability challenges). The FESS course had thirteen sessions, and the DTS course had twelve sessions (due to a public holiday). The FESS course was implemented in the autumn semester of 2020; the lessons learned from the implementation along with the suggestions from the participants were incorporated in the DT toolkit. The toolkit was also aligned to the context and needs based on the first four steps of the ecological design before implementation in the DTS course during the spring semester of 2021. The changes were minor and improved the toolkit further.

Out of thirteen sessions of the FESS course, ten sessions were conducted online, and three sessions were conducted face-to-face.

Table 4
. Description of cases.

Case	Course	Level	Objective	Implementation timeline	Mode
University of Tokyo, Japan	Field Exercise Course in Sustainability Science (FESS)	Graduate – Open to all departments	Frame sustainability challenges in Kashiwa no ha area and then propose innovative solution ideas for the framed challenges	October 14, 2020 till January 13, 2021 Autumn Semester	Hybrid
Leuphana University, Germany	Design Thinking for Sustainability (DTS), Complimentary Course	Undergraduate - Open to all academic majors	Frame sustainability challenges related to biodiversity in the district of Oldenburg (Hude municipality) and then propose solutions and response ideas to deal with the framed challenges.	April 12, 2021 till July 5, 2021 Spring Semester	Digital

Introduction	Empathize	Define (Problem Framing)	Ideate	Prototype	Present	
Session 1-2	Session 3-4	Session 5-7	Session 8-9	Session 10-12	Session 13	FESS
Session 1-2	Session 3-4	Session 5-7	Session 8-9	Session 10-11	Session 12	DTS

Fig. 3. The allocation of sessions to each stage of Design Thinking for FESS and DTS.

Two face-to-face sessions were held during the empathize stage, and the third face-to-face session was organized during the proto-typing stage. In the DTS course, all 12 sessions were conducted online. Fig. 3 represents the allocation of sessions to each stage of DT for FESS and DTS.

DT tools were converted into a digital format using Miro boards; to facilitate virtual teamwork, utilize DT tools, and record the teams' progress. Figs. 4 and 5 represent a segment of the team-2′s Miro board from FESS and team-3′s Miro board from DTS. The zoom video call function was used to hold online sessions and break-out groups function was used to assist teamwork.

The components of FESS and DTS courses were aligned to the six components of the DTP framework, and Table 5 represents the components of the courses aligned to the DTP framework.

Both FESS and DTS courses were open, for registrations, to students from different academic majors/departments. Eleven graduate students (five males and six females) registered and attended the FESS course, and they were divided into two teams. DTS started with twenty-four undergraduate students, and some of them dropped off between the first and third sessions; finally, sixteen students (six males and ten females) participated in the DTS course until the end, divided into five teams. See Table 6 for more details on the characteristics of participating students. Teams in both courses were formulated based on each student's background (regional, disciplinary, personality) to ensure diversity in each team. The data on students' background was collected during the first (intro-ductory) session, students were put into teams from the second session, and they worked in teams throughout the course.

4.3. Data collection - capturing participants perspectives

Participants' perspectives were captured based on the DTP framework to explore participants' experiences during the two courses. Collecting participants' experiences of the learning processes and environment play a key role as it cannot be assumed that the six components of the DTP framework incorporated by the educator, via DT pedagogy, will translate into participants experiencing those components during the course.

For FESS, participants' perspectives were captured via reflection sheets, observations, and semi-structured interviews. Participants' perspectives for the DTS course were captured through reflection sheets, observations, final reflection reports, and semi-structured interviews. Table 7 elaborates on details of the data collection scheme for each case.

Reflection sheets, created using Google forms, were circulated and filled voluntarily by the participants after each session. Ob-servations were recorded by inspecting the teams' Miro boards (taking snapshots) and discussions in the zoom breakout groups during the sessions throughout the course (collating the notes in the form of memos). Semi-structured interviews for both cases, were con-ducted online through the Zoom video conferencing feature. Zoom is a viable tool for qualitative data collection because of its ease of use, cost-effectiveness, security selections, and data management features (Archibald et al., 2019). Each interview was 35–50 min long and recorded via the Zoom recording feature. All the participants from DTS were asked to submit a 3–5 page long (final) reflective report to elaborate on; their experiences during each stage of DT while working on their projects and if DT can be useful for them.

4.4. Ethical considerations

The research participants agreed to provide their informed consent. Informed consent was developed to get an agreement from the participants on their participation in the research, research procedures, research purpose, voluntary nature of participation, measures used to ensure confidentiality, benefits, and research risks. Data was collected, anonymized, and kept in the password-protected computer - only accessible to the authors.

Fig. 4. A segment of team −2′s Miro board from FESS.

Fig. 5. A segment of team −3′s Miro board from DTS.

4.5. Data analysis

Data collected from both courses (FESS and DTS) was transcribed and analyzed using MAXQDA. MAXQDA is a software program used to analyze qualitative and mixed methods data (Kuckartz- & Rädiker, 2019). Initially, the two data sets collected from the FESS course and DTS course were analyzed separately, using thematic analysis (Boyatzis, 1998; Braun & Clarke, 2012), where the initial coding was primarily deductive based on, research-driven, six components of the DTP framework. The second round of coding was inductive. Data sets were analyzed in the steps elaborated in Table 8 (Boyatzis, 1998; Braun & Clarke, 2012; Kuckartz- & Rädiker, 2019; Pearse, 2019).

The research used intercoder agreement (Silverman, 2005; Tinsley and Weiss, 1975) as the first author conducted the data analysis followed by the data analysis conducted by an outside coder, and then the second author checked the themes aligned to the codes. There were no significant variances, and slight discrepancies were discussed and addressed to conclude the set of themes presented in the study (see Table 9). Quotes demonstrating the findings and interpretation arising from the data while capturing participants' emotions and experiences (Eldh et al., 2020) were selected to support the explanation of themes in the result section.

5. Results

This section presents the seven themes prevalent in the data, probing participants' perspectives on their experiences regarding six critical components of the DTP framework during the FESS and DTS to explore DT as DTP. The themes which emerged from the data are: (a) Content; (b) Perspectives; (c) Process; (d) Context; (e) Digital Tools; (f) Facilitation; (g) Global vs Local Interconnection. The first six themes are based on the deductive analysis, based on the DTP framework (inductive codes were also added to these themes), which also reveals that participants experienced all the components of the DTP framework. Two cases model with 14 most frequent common codes (Fig. 6) based on the data collected from FESS and DTS, extracted from MAXQDA, also confirms that the data from both cases have codes aligned to the DTP framework. The seven emerging themes are explained as follows, and related concepts and quotes from each theme are listed in Table 10.

5.1. Content

Sustainability was set as the theme (content) of FESS, where participants tried to understand sustainability challenges in the Kashiwa no ha area during the empathize stage, followed by framing a sustainability problem based on their empathize findings. In DTS, participants were asked to explore and frame a sustainability challenge linked to biodiversity, and biodiversity was set as the content of the course. In both cases, participants understood that sustainability challenges are multidimensional, and dealing with them requires considering different perspectives (Table 10, Q1). This understanding also encouraged participants to recognize the importance of multiple perspectives.

DT pedagogy took an interdisciplinary approach by putting learners into diverse (multidisciplinary) teams and exposed them to each other's perspectives, stakeholders' perspectives, and perspectives from literature (past reports), on the respective sustainability issues (Table 10, Q2). This setup promoted transdisciplinary thinking as learners established a shared understanding of the content within teams by incorporating multiple perspectives, leading to a common conceptual framework (understanding) which provided new insights about the sustainability challenge (theme) and opportunities for collaborative value (idea) creation. A similar interdisciplinary approach is reported by Leblanc (2009) to encourage trans-disciplinarity in teaching and building transdisciplinary thinking among learners. Fig. 7 represents the visual depiction of this process. Exposure to different perspectives regarding the content allowed learners to connect new perspectives to their previous understanding and then construct a new meaning (understanding), which was

Table 5

The components of the courses aligned to the DTP framework.

Component of DTP framework	Course Component/s		Mode	Placement in the Course
Content	FESS	Participants were asked to frame a sustainability challenge in Kashiwa no ha area and ideate solutions for the framed challenge. Sustainability was set up as theme of the course. Teams identified the sustainability challenges based on the empathize stage findings and then worked towards finding solutions for the framed challenges.	Hybrid	Throughout the course
	DTS	During DTS, biodiversity was set up as a broad theme of the course. Participants were asked to frame a sustainability challenge linked to biodiversity in Oldenburg district area. Teams identified the sustainability challenges linked to biodiversity based on the empathize stage findings and then worked towards finding solutions for the framed challenges.	Online	Throughout the course
Perspective	FESS	Interviews with the stakeholders (community members, local government, academia and private sector) from Kashiwa-no-ha area to get their perspectives on sustainability challenges in the area.	Face-to-face	During the empathize (1st) stage of DT
		Field visit of Kashiwa no ha area to get insights on what community members experience in the area.	Face-to-face	During the empathize (1st) stage of DT
		Presentations from experts (stakeholders involved in development of Kashiwa-no-ha area from government, academia, and private sector) followed by discussion	Face-to-face	During the empathize (1st) stage of DT
		Follow up interviews the community members and stakeholders (local government, academia, and private sector) from Kashiwa-no-ha area.	Online	During the problem framing (2nd) and ideation stage (3rd)
		Team formation- Participants were divided into (diverse) teams. Teams were formed based on each student's background (regional, disciplinary, cultural and personality) to make sure that teams are as diverse as possible to expose participants to diverse perspectives. Participants worked in the allocated team throughout the course.	Hybrid	Introductory session
		Teambuilding activities were organized before starting teamwork during the introductory sessions to encourage collaboration and perspective sharing among the teams.	Online	Introductory session
		Teams were encouraged to establish a communication channel in the form of social networking team's group to ensure effective communication between team members.	Online	Throughout the course
		Teams were given tasks that encouraged them to meet and work together besides the scheduled sessions.	Hybrid	Throughout the course
		During the course all the tasks were assigned to the team and assessed based on teams' performance which encouraged collaboration and perspective sharing.	Online	Throughout the course
	DTS	Interviews with the stakeholders (community members, local government, academia, private sector and non-profits) from Oldenburg area to get their perspectives on sustainability challenges linked to biodiversity in the area.	Online	During the empathize (1st) stage of DT
		Team formation- Participants were divided into (diverse) teams. Teams were formed based on each student's background (regional, disciplinary, cultural and personality) to make sure that teams are as diverse as possible to expose participants to diverse perspectives. Participants worked in the allocated team throughout the course.	Online	Introductory session
		Teambuilding activities were organized before starting teamwork during the introductory sessions to encourage collaboration and perspective sharing among the teams.	Online	Introductory session
		Teams were encouraged to establish a communication channel in the form of social networking team's group to ensure effective communication between team members.	Online	Throughout the course
		Teams were given tasks that encouraged them to meet and work together besides the scheduled sessions.	Online	Throughout the course
Process	FESS	Design Thinking (DT) pedagogy was used to implement the course, which was flexible and self-directed. DT tools were provided to the participants, for each stage of DT, to give methodological guideline to support framing the sustainability challenge in Kashiwa-no-ha area and proposing solution ideas by the end of the course. However, each team used these tools according to their own topic of interest and needs. All tasks performed, using the tools, had real world relevance and they were participatory in nature.	Hybrid	Throughout the course
		Progress checks were planned - one after define stage, one after ideate stage and one after prototyping stage. Each team had to fulfill the requirements of the progress checks and go through the check with the teaching team to progress to the next stage of DT. The progress checks were planned to encourage participation in the planned activities	Hybrid	End of define (2nd), ideate (3rd) and prototyping (4th) stages
		Final presentations were organized, where each team presented a summarized version of their project. The presentation included the framed sustainability challenge in Kashiwa-no-ha area and the finalized, feasible, solution idea. A clear scoring criterion was provided to the participants to prepare the final	Online	Last session (5th stage)

Table 5 (*continued*)

Component of DTP framework	Course Component/s		Mode	Placement in the Course
		presentations. Stakeholders from Kashiwa-no-ha area were also invited to attend the final presentations. Final presentations intended to encourage engagement and completion of the planned activities.		
	DTS	Design Thinking (DT) pedagogy was used to implement the course, which was flexible and self-directed. DT tools were provided to the participants, for each stage of DT, to give methodological guideline to support framing the sustainability challenge linked to biodiversity in Oldenburg area and proposing solution ideas by the end of the course. However, each team used these tools according to their own topic of interest and needs. All tasks performed, using the tools, had real world relevance and they were participatory in nature.	Online	Throughout the course
		Progress checks were planned - one after define stage, one after ideate stage and one after prototyping stage. Each team had to fulfill the requirements of the progress checks and go through the check with the teaching team to progress to the next stage of DT. The progress checks encouraged their participation in the planned activities	Online	End of define (2nd), ideate (3rd) and prototyping (4th) stages
		Final presentations were organized, where each team presented a summarized version of their project. The presentation included the framed sustainability challenge in Oldenburg area and the finalized, feasible, solution idea. A clear scoring criterion was provided to the participants to prepare the final presentations. Final presentations intended to encourage engagement and completion of the planned activities.	Online	Last session (5th stage)
Context	FESS	Kashiwa-no-ha area in Kashiwa city, Chiba prefecture, Japan was selected to set up the context. The context (Kashiwa-no-ha area) set for the course was all embracing to create real-world relevance to offer motivation and purpose for learning to the participants along with a sustained and complex learning environment.	Hybrid	Throughout the course
	DTS	Hude municipality, Oldenburg District, Germany, was selected to set up the context. The context (Hude municipality, Oldenburg) set for the course was all embracing to created real-world relevance to offer motivation and purpose for learning to the participants along with a sustained and complex learning environment.	Online	Throughout the course
Digital Tools	FESS	Digital tools including Miro boards, Zoom platform, and Google forms were used to run the course. These tools were designed according to the requirements of each stage of the course and used throughout the course	Online	Throughout the course
	DTS			
Facilitation	FESS	Members of the teaching team, including one faculty member from GPSS-GLI and three teaching assistants from the doctoral program of GPSS-GLI, facilitated the DT pedagogy during the course. Educators took a facilitator's (coaching) role to support the teams and only intervened if they got stuck or requested for help.	Hybrid	Throughout the course
		Peer feedback sessions were organized at the end of each stage of DT where teams gave feedback to each other on the outcomes of each stage of DT. Peer feedback sessions also served as peer facilitation/coaching sessions.	Online	End of each DT stage
	DTS	Members of the teaching team, including one faculty member from the Leuphana University and an external lecturer from the doctoral program of GPSS-GLI, the University of Tokyo, facilitated the DT pedagogy during the course. Educators took a facilitator's (coaching) role to support the teams and only intervened if they got stuck or requested for help.	Online	Throughout the course
		Peer feedback sessions were organized at the end of each stage of DT where teams gave feedback to each other on the outcomes of each stage of DT. Peer feedback sessions also served as peer facilitation/coaching sessions.	Online	End of each DT stage

shared within the respective teams. Establishing new meaning (shared understanding) required individuals to get involved in discourse within the teams and critically reflect on their previous understanding. Through these radically collaborative teamwork experiences, learners in both cases mentioned learning communication skills, tolerance, and confidence (Table 10, Q3, Q4).

5.2. Perspective

Participants in FESS and DTS expressed that they were exposed to multiple perspectives via expert presentations, stakeholder interviews, group work, and feedback from peers (Table 10 Q5, Q6). As a result, participants encountered ontological perspectives from different sources to understand the sustainability challenge from different dimensions. Furthermore, these perspectives were both cognitive and affective as participants explored perspectives on thoughts and beliefs about sustainability issues and people's emotions and feelings related to the sustainability challenge (Table 10, Q7, Q8). Being exposed to diverse perspectives in a team setting, participants in both cases became aware that their opinions might differ from their teammates', which made them more open to different perspectives while understanding their own positions (Table 10, Q9). Participants shared that the course has changed the way they approach the problem, and they have learned to become more attentive towards multiple perspectives and look at the problem from

Table 6

Characteristics of course participants (students) in FESS & DTS.

Course	Participant Code	Gender	Academic Background	Regional Background	Personality [1]
FESS	FA1	M	Natural Science	Asia, China	Do
	FA2	M	Humanities	America, United States of America	Say
	FA3	F	Natural Science	Asia, Indonesia	Think/Feel
	FA4	F	Engineering	Europe, Italy	Do
	FA5	F	Social Science	Asia, Japan	Feel
	FA6	F	Natural Science	America, Brazil	Feel
	FA7	M	Social Science	Asia, Indonesia	Do
	FA8	F	Other - Sustainability Science	Asia, Vietnam	Do
	FA9	F	Social Science	Asia, China	Feel
	FA19	M	Others - Natural Science & Social Science	Asia, Philippines	Feel
	FA11	M	Engineering	Asia, Japan	Think
Course	**Participant Code**	**Gender**	**Academic Background**	**Regional Background– Geographical Provenance [2]**	**Personality [1]**
DTS	DS1	F	Studium Individuale	Small City	Feel
	DS2	F	Environmental Sciences	Big City	Feel
	DS3	M	International Business & Entrepreneurship	Small City	Do
	DS4	M	Business	Small City	Feel
	DS5	M	Environmental Sciences	Sub-Urban	Say/Feel
	DS6	F	Business Administration	Rural	Feel
	DS7	F	Economics (Volkswirtschaftslehre)	Sub-Urban	Feel
	DS8	F	Environmental Studies	Sub-Urban	Say
	DS9	M	Cultural Science Studies	Big City	Say
	DS10	F	Environmental Science	Rural	Say/Do
	DS11	F	Business Law	Small City	Do
	DS12	F	Environmental Sciences	Rural	Feel
	DS13	M	Business Administration	Small City	Feel
	DS14	F	Environmental Science	Big City	Say
	DS15	M	Environmental Science	Small City	Mix of all 4 Say, Feel, Think and Do.
	DS16	F	Humanities	Rural	Feel/Think

[1] Personality: **Say** (Outgoing, articulate, storyteller, spontaneous**); Feel** (Empathetic, diplomatic, relationship-oriented); **Think** (Knowledgeable, methodical, structured, reserved);**Do** (Action-oriented, gets things done, focused, risk-seeking).

[2] All the participants in DTS were from Germany therefore, their regional background was collected in the form of geographical provenance.

Table 7

Data collection scheme for both cases (FESS & DTS).

Case	Reflection Sheets	Semi Structured Interviews	Individual Reflective Report	Observations
FESS	Throughout the Course - Circulated as Google form after each session. 143 sheets (Voluntarily filled by the end of each session)	$n = 11$ 11 transcripts (Conducted between Jan 14 and Jan 19, 2021)	N/A	Throughout the Course: Miro boards & Zoom breakout sessions: via snapshots & memos
DTS	Throughout the Course - Circulated as Google form after each session. 40 sheets (Voluntarily filled by the end of each session)	$n = 3$ 3 transcripts (Conducted between Jan 14 and Jan 19, 2021)	$n = 15$ 15 individual reflective reports (Received by September 15, 2021)	Throughout the Course: Miro boards & Zoom breakout sessions: via snapshots & memos

different dimensions. This encouraged open-mindedness and system thinking among the participants (Table 10, Q10, Q11).

During FESS and DTS, participants not only encountered multiple perspectives through the experiences provided by DT pedagogy, but these experiences also challenged their perspectives. Participants had pre-conceptions/assumptions based on their past experiences, and when they encountered new experiences during FESS and DTS, their previous perspectives were challenged, leading to the feeling of enlightenment, or being surprised (Table 10, Q12). Some participants in the FESS course shared that they felt uncomfortable when they were confronted with a different perspective or when their perspectives were being challenged (Table 10, Q13).

5.3. Process

Participants of FESS and DTS appreciated the practicality of the course and exposure to active and experiential learning (Table 10, Q14, Q15). Progress checks designed to encourage participation in the DT tools helped keeping the participants engaged in both

Table 8
Steps for data analysis.

Steps for Data Analysis
a Transcription and Labeling;
a Familiarization (examination of data for immersion);
a Codebook development in MAXQDA with 6 codes based on DTP framework;
a Initial coding based in the codebook (deductively);
a Adding codes (inductively) to extend the analysis beyond the theoretical propositions set by the DTP framework. 15 additional codes were added to the codebook in the FESS data set, and 12 additional codes were added to the codebook in the DTS data set;
a Identifying themes by exploring patterns in the data and grouping codes. Initially, 13 themes were identified in the FESS data set and 10 in the DTS data set;
a Reviewing – The identified themes were reviewed in relation to the coded data and entire data set. After reviewing, 10 themes were identified in the FESS data set, and 9 were identified in the DTS data set. After identifying and reviewing themes in both data sets, data sets from FESS and DTS were merged where overlapping themes were combined. Themes were reviewed again, 8 themes emerged and after the last round of review 7 themes were finalized (Table 9).

Table 9
Finalized themes and aligning codes and the number of coded segments.

Theme	Code	Coded segments
Content	Content	29
	New experience	14
Perspectives	Perspectives	71
	Challenging perspectives	22
	Uncomfortable	8
Process	Process	34
	Fun	16
	Hard	9
	Engagement	7
	Teamwork	14
	Taking forward	14
	Teambuilding	8
	Improvement-Process	5
	Useful	14
Context	Context	19
	Real world relevance	8
	Improvement-Context	7
Digital Tools	Digital Tools	20
	Visualization	12
	Satisfaction	7
Facilitation	Facilitation	23
Global vs Local Interconnection	Global Vs Local	7
	Critique	

courses and assisted their progress through the stages of DT pedagogy. While appreciating the process, participants in both cases recognized the importance of each stage of DT pedagogy (Table 10, Q16). Participants enjoyed the process and had fun while working on complex sustainability challenges. Many DTS participants also discussed the importance and potential of using DT tools in their individual reports. They found these tools useful for their projects during the course and expressed the intention to use them in future projects (Table 10, Q17, Q18).

Participants in both courses were actively involved in dealing with sustainability challenges in their respective areas, which empowered and inspired them to stay engaged with the community and take their projects forward towards reality (Table 10, Q19, Q20).

Participants from DTS and FESS elucidated problem framing as the most challenging part of the course. The journey map, drawn by the participants in both cases, also indicated back and forth movement during the problem framing stage, indicating complexity and difficulty (e.g., see Figs. 8 and 9 showing journey map of team 1 from DTS & FESS, respectively on Miro board). The DT tools provided to the participants during the problem framing stage required participants to narrow down the scope of the problem while seeing the problem from different dimensions. Teams kept moving back and forth during the problem framing stage to confirm their assumptions while narrowing down the scope of the problem. Participants found it challenging to narrow down the scope of the problem because that made the differences between the teammates more visible, exposing them to more uncomfortable confrontations. Dealing with these uncomfortable confrontations was difficult during the initial stages because participants from different backgrounds struggled to bond as a team. Participants from both cases mentioned that the early stages of DT pedagogy were difficult because they had just started teamwork and did not know much about their teammates (Table 10, Q21). Participants from DTS also mentioned prototyping as a difficult stage as it was reduced to two sessions compared to three sessions in FESS and prototyping experience in the digital settings was new for the participants (Table 10, Q22).
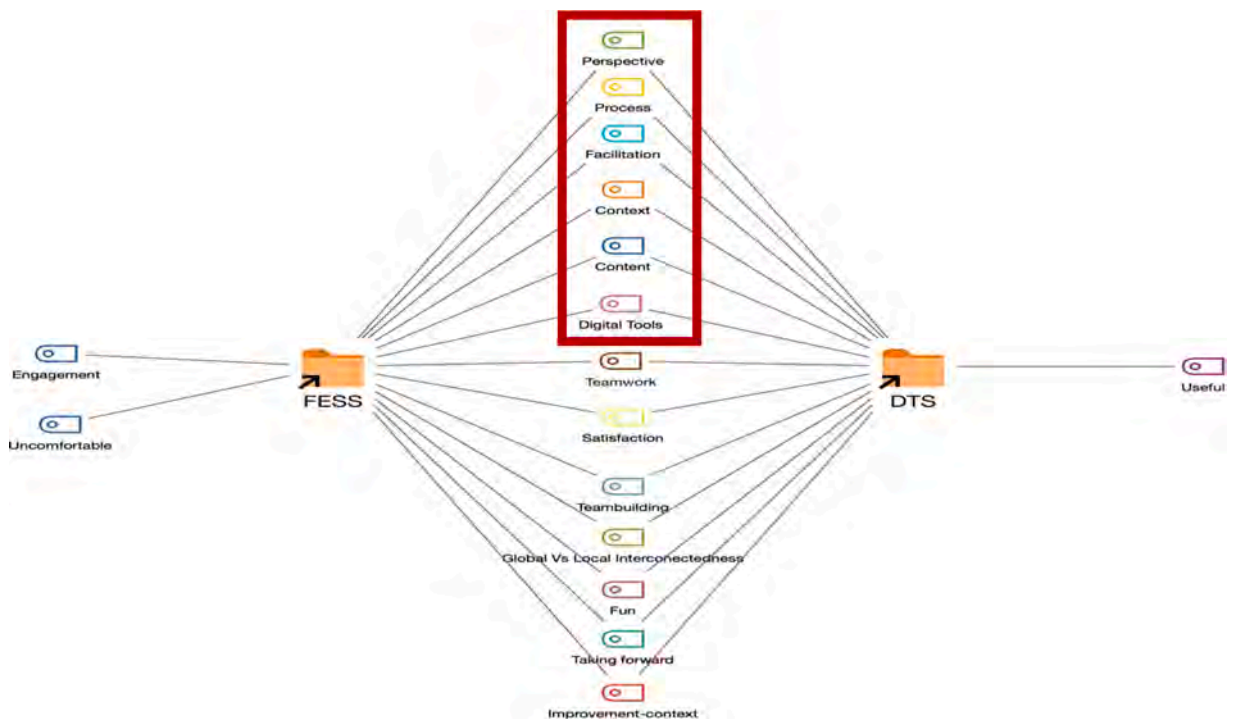
Fig. 6. Two cases model (with 14 most frequent common codes) for FESS & DTS indicating codes aligned to DTP framework components.

In terms of improving the process and making it more experiential, participants from FESS suggested allowing more flexibility in using the DT tools and sharing (and using) their own tools (strategies) for different stages of DT. On the other hand, DTS participants suggested adding more tools (substitutive tools) to the toolkit so that learners can have more choice and flexibility in selecting the tools to go through different stages of DT (Table 10, Q23, Q24).

5.4. Context

Participants in both courses recognized that conducting this course in a specific context made it easier to approach the sustainability challenge and propose ideas to deal with that challenge (Table 10, Q25). Attaching the course to the geographical context allowed FESS and DTS participants to see the real-world relevance of the courses, and they expressed that they have worked towards dealing with real world challenges (Table 10, Q26, 27). In addition, the real world experiences provided during the course made it easier to apply the learnings from these experiences to the real world (Table 10, Q28).

The context set for both courses was determined and incorporated in the courses while designing the course. In both cases, the university already had previous engagements with the context. For example, Kashiwa no ha, set as a context for FESS, utilizes a public-private-academia governance structure, and Urban Design Center Kashiwanoha (UDCK) provides a foothold for this collaboration to develop the town. Since 2015, UDCK and the University of Tokyo have been engaged in a field exercise course that takes Kashiwa no ha as the subject of research interest for participating students (UDCK, 2018). Similarly, Hude municipality, Oldenburg, was set as a context for DTS. The course was built on the former research collaboration of Leuphana University in the district of Oldenburg, which started in 2016, i.e., transdisciplinary case study: (Bio)Diversity Corridor, Leverage Points for Sustainability Transformation (Leuphana University, 2021). The existing collaborations with the area set as the context, in both cases, allowed the teaching team to share the reading material/reports on pre-existing research projects/exercises in the area to provide the background knowledge regarding the area and to get diverse stakeholders on board to provide multiple perspectives to the participating students. This highlights the importance of university-community/region partnership to promote sustainable development in the municipality/region. Universities can provide expert knowledge needed by the community/region for its sustainable development. Concurrently, local knowledge embedded in the context can be provided by the communities to the universities for their activities.

All sessions for DTS were conducted in digital settings; therefore, some participants found it difficult to relate to the landscape of Hude municipality (Table 10, Q29, 30). Another participant from DTS, while suggesting improvement in the context of the course in the digital settings, proposed to introduce virtual trips through live or drone videos or clips.

5.5. Digital tools

Participants in both courses appreciated the Miro board as a digital tool and its design, which supported all the components of the

Table 10

Summarized results with themes, key concepts and supporting quotes.

Theme	Key concept	Quotes (Q)
Content	Participants' perspectives on the content of the course	**Q1.** "Sustainability challenges need transdisciplinary or multidisciplinary approach…so I think that talking to different stakeholders and trying to find the problem, even though we wanted to help citizens the most but by interviewing other stakeholders got to find real problems." (Participant-FESS).**Q2.** "*…my teammate do not know much about sustainability, but I think because of the group work then, now she knows more about sustainability and biodiversity, and the course materials like biodiversity corridor also helped.*" (Participant-DTS). **Q3.** "I got more confident, much better than before. Mainly it is because I had a lot of opportunities to discuss with the group members, and in the discussion, I tried to voice my ideas and opinions." (Participant-FESS).**Q4.** "Working together with a very diverse group of people also gave a great outlook for professional life after the studies." (Participant-DTS).
Perspectives	Participants' perspectives on engagement with diverse perspectives	**Q5.** "In the group setting, six of us coming from different backgrounds and we have a different point of view….I will say yeah! I encountered multiple perspectives." (Participant-FESS). **Q6.** "Interview was the best way to understand the position, thoughts, and feelings of stakeholders and an optimal tool to receive more information." (Participant-DTS). **Q7.** "Initially we thought that the X party(stakeholder) was slacking off because we heard too many complains from the residents of Kashiwa no ha and we got biased… When we interviewed Y san (a representative of the X party), our team discussed that the problem is something else." (Participant-FESS). **Q8.** "In the second interview, "M" san showed the willingness to join the community event… And after talking to residents, I found that many people are willing to join that kind of event, they need the place to gather and interact with other people to build a sense of community, it was surprising for me!" (Participant-FESS). **Q9.** "One's own opinion will not always coincide with that of the other team members. There will be discussions in which all team members have to show a certain tolerance… Only if this tolerant and reflective approach can be ensured Design Thinking will work." (Participant-DTS). **Q10.** "… now I pay more attention to different perspectives that we need to think from different point of views and then get a complete sense of the problem." (Participant-FESS). **Q11.** "…it also opened my mind." (Participant-DTS). **Q12.** "… I think it is, it is very necessary to have, especially in university, to clash with people, not fight, but to approve that the beliefs you hold are still true and valid and also to change them accordingly to new perspectives and data…For example, …when we interviewed the conventional farmer, it was really interesting to see how he perceives the whole debate around climate change and cost-effective production. He says he is forced into monoculture because of no compensation being offered, and this is a kind of perspective I have not seen before. So it was very enlightening." (Participant-DTS). **Q13.** "…It (confrontation) made me uncomfortable…I can feel some tension with the differences…".(Participant-FESS).
Process	Participants 'perspectives on opportunities for direct participation and experiential learning	**Q14.** "…because we were really given hands-off…there was obviously guidelines to follow, but the way that we met those guidelines, and the way that our team wanted to go was very much our own decision." (Participant-FESS). **Q15.** "…the thing that triggered me to do the design thinking complementary was because it was very practical, and it was in the municipality of Hude". (Participant-DTS). **Q16.** "it was equally valuable for me to be able to look back and summarize that each phase play a role in the process and why it is so important to go through these steps one after the other." (Participant-DTS). **Q17.** "…practicing these tools in the course, together with students who never did it before, it was eye-opening, how useful they can be!" (Participant-DTS). **Q18.** "…design thinking tools are handy for the future career." (Participant-DTS). **Q19.** "I just feel more comfortable and engaged with the actual Kashiwa no ha, space, this community area and I want to get involved once things start to pick up again after COVID" (Participant-FESS). **Q20.** "The projects are really practical, and I want to go to Hude and maybe do this in future."(Participant-DTS). **Q21.** "…early stages where not only the coursework was pretty difficult like

Table 10 (*continued*)

Theme	Key concept	Quotes (Q)
		the problem framing, but also where we were not solidified as a team yet." (Participant – FESS). **Q22.** "Prototyping was hard, we collected the material, but we were not sure what we want to do, and time was running out… but then we somehow did it, and that was fun…." (Participant-DTS). **Q23.** "we can follow a basic step by step process, but allow our own way instead of using specific tools….may be if you allow time for all of us to, to talk to each other about our own approach and then use that…" (Participant – FESS). **Q24.** "I'd suggest a little methodological pool with substitutive methods aiming for the same outcome." (Participant – DTS).
Context	Participants' perspectives on their engagement with the context (place) where learning is rooted	**Q25.** "I think, with Hude, it was much easier … for example, you can look on the website and have the interview with the experts from the municipality and get to know more about the problems or challenges they have, and in the reading materials provided during the course, we discovered much about Hude and the flowers stripes, and so on…" (Participant-DTS). **Q26.** "Our project is about Kashiwa-no-ha, which is the living laboratory for us to do research, and we did our own idea research. It is very real! We are tackling real problems." (Participant-FESS). **Q27.** "*it was super complimentary because it was like the practical part to all the theory we had learned, and seeing that in the end we could actually achieve something and come up with a good idea, which can be used.*" (Participant-DTS). **Q28.** "*I have never really gotten to engage with people on the ground, and so it was a really good exercise and learning point for me because I started to apply this, the stuff I've learned in the classroom, to actual people, real life people.*" (Participant-FESS). **Q29.** "…I know some regions around Hude, but in the context of the whole course, I did not get to visit Hude one time because of COVID, so it was already very abstract and I did not get to experience Hude at all." (Participant-DTS) **Q30.** "*It was really sad we can*no go there, like, have a look at how it is like …" (Participant-DTS).
Digital Tools	Participants' perspectives on extent to which digital/technological tools supported learning and course design	**Q31.** "I was quite surprised! I was literally thinking it is not going to work online because like 90% was online work, but Miro boards made this work…" (Participant-FESS) **Q32.** "…it (Miro board) was an excellent tool to help us stay on track. Also, very well prepared miro boards… that is really good because we always knew what is next." (Participant-DTS). **Q33.** "…it is meaningful to try to visualize the thinking process and reflect on our work on Miro boards from the beginning to the final part because it will be easy to go to the previous stage when we have problems." (Participant-FESS). **Q34.** "I think I'm very proud looking at our Miro board, it was a lot of work that we have done, and now we know it is mostly the end…" (Participant-DTS).
Facilitation	Participants' perspectives on coaching and support provided by the teaching team	**Q35.** "…if we have problems, we can just go to the teaching team asking for help… And also, classmates, you know we are helping each other quite much. It is good!".(Participant-FESS). **Q36.** ".. we were never told "no" it is not a good idea…we felt free to say whatever we want to say…I mean it was all under a polite environment, and as a student, I always felt like this is a good situation, and you can speak up, and no one will judge you."(Participant-DTS). **Q37.** "*…every time we got stuck, the facilitators (teaching team) gave us some suggestions or comments to help us to continue the discussion.*"(Participant-FESS). **Q38.** "…we have the feeling that when we do not know how to go on, every time we can go to x & y (teaching team) and say, we need help!"(Participant-DTS).
Global Vs Local Interconnectedness	Participants' critique on using DT to deal with sustainability challenges	**Q39.** "…when we are using this approach, we are looking at the thing as a very specific lens…" (Participant-FESS). **Q40.** "One problem I see, is that the solution ideas from the design thinking often refer to a specific area and scope, whereas problems like biodiversity loss and climate change have broader scope and cannot always be narrowed down to a specific area." (Participant-DTS).

courses (Table 10, Q31). In addition, participants acknowledged that Miro boards supported their progress during the course and helped them move forward (Table 10, Q32). While using Miro boards, participants saw the importance of visualizing: information, thinking process, and team's progress. Visualization enabled the participants to reflect effectively and see their progress till the end (Table 10, Q33). Seeing the progress from beginning until the end developed a sense of appreciation, pride, and satisfaction among the participants (Table 10, Q34).
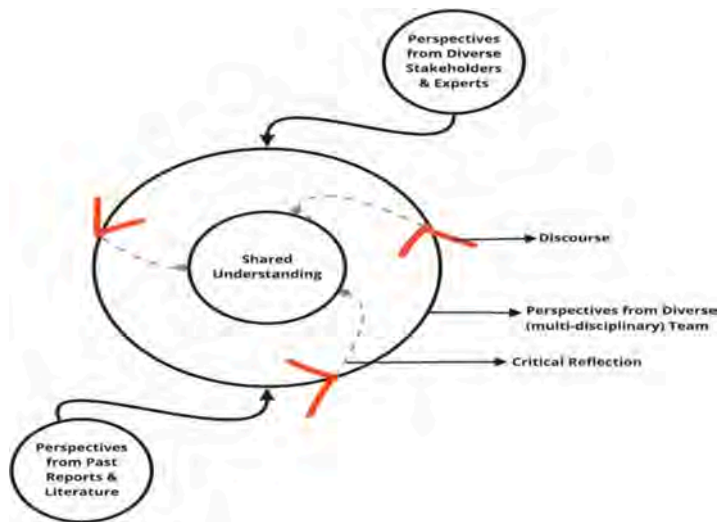
Fig. 7. Establishing a shared understanding on the sustainability content and fostering transdisciplinary thinking via interdisciplinary approach.
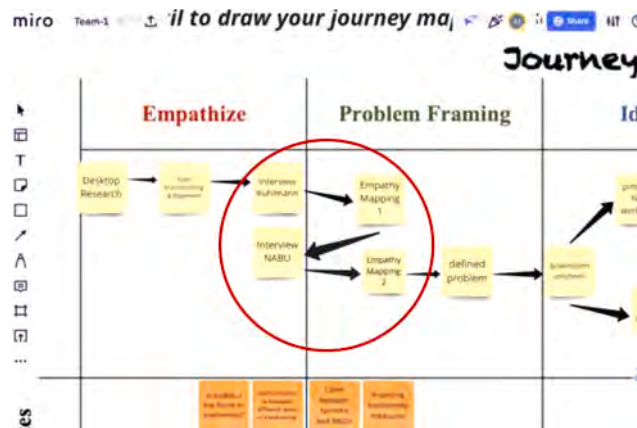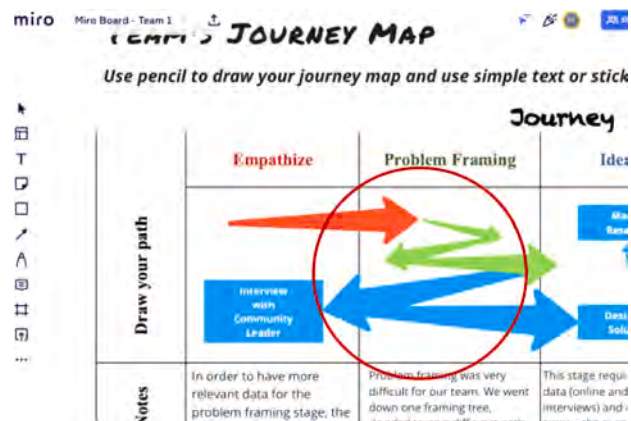

Fig. 8. . Team-1's journey map-DTS.

Fig. 9. . Team-1's journey map-FESS.

5.6. Facilitation

In both cases, the teaching team supported the learning process and environment by taking the role of facilitators and extended their support when needed (Table 10, Q35). Participants also received support from their peers. Facilitation created an empowering and comfortable environment allowing participants to engage in free, autonomous, and constructive discussions (Table 10, Q36). It was noted that facilitation specifically supported the flow of discussions during the FESS. During DTS, facilitation mainly supported teamwork, e.g., in one of the teams, two team members dropped out during the first three weeks. That team was struggling with teamwork, and way forward - one-on-one meetings were conducted with the group to support teamwork and motivate them (Table 10, Q37, Q38).

5.7. Global Vs local interconnectedness

An unexpected critique emerged from data collected from both courses (FESS & DTS) regarding the scope of the sustainability problems that DT can tackle. Participants mentioned that DT makes the problem very specific and narrow, which may not apply to the challenges at the global scale Table 10, Q39, Q40). Through DT pedagogy, understanding the systemic problems underneath the superficial issues and conflicts narrows down the scope of the problem.

Although the current study understands and appreciates the critique, it also counters it by adding that sustainability challenges are global challenges, but their manifestations are local and contextual. Local and contextualized action is essential to deal with sustainability challenges on a global scale. Therefore, despite operating globally, many research institutions and non-governmental organizations (NGOs) conduct their co-production activities for sustainability research at local level with local partnerships (Norström et al., 2020). The global vs. local critique can also relate to how sustainability problems are approached in HSE, based on theoretical knowledge about the sustainability problems, which is vital for understanding the whole mechanism. But when it comes to going one step forward and dealing with these problems, it is challenging to find responses for holistically framed problems because they are not actionable. HSE is not only problem-focused but also solution-oriented, and it aims to build leaders who can deal with sustainability challenges in their respective communities (local actions), which will contribute towards global sustainability.

6. Discussion

The current research aims to explore if DT as DTP could set the learning processes and environment aligned to the six components of the DTP framework in HSE. Two case studies (FESS and DTS) were conducted to achieve this purpose. The detailed experiences of the participants apprehended by in-depth interviews, reflections (sheets & reports), and observations revealed that participants in both cases experienced the six components of the DTP framework while going through the DT pedagogy during the course. These components include content, perspective, process, context, digital tools, and facilitation.

In both cases, participants were provided with diverse perspectives from different sources (diverse stakeholders, peers, experts, teaching team) in the team setting. According to Mezirow, perspectives are composed of sets of values, beliefs, and assumptions that we acquire through experiences, and they are the lens through which we view the world. These perspectives, being helpful, can sometimes be biased and flawed, leading to distorting our ability to perceive and be open to new views and ideas. Furthermore, Mezirow suggests that we can identify, assess, and act to modify(transform) our perspectives through discourse and critical reflection. Disorienting dilemmas, discourse, and critical reflection are necessary conditions for transformative learning (Mezirow, 1991). Disorienting dilemmas are the experiences (stimulus) that lead a person to question their own perspective and go through the perspective transformation. Disorientation brings in an element of critical discourse to reflect upon the situation or subject with others. In both cases, disorientation, provided to the participants through diverse perspectives, challenged their previous perspectives as they reflected

Fig. 10. . Team-1's Empathy Map - FESS.

critically on their previous perspectives after being exposed to new perspectives. For example, a participant from a team in DTS working on third-order water bodies to protect the aquatic biodiversity in Hude mentioned that initially, her perspective was that the farmers should do something to protect these water bodies. After encountering the perspectives from the farmers and one of the peers (whose parents were farmers), the perspective about the problem's reality was challenged, and their team changed their problem framing. The same participant said: "…I think these perspectives are very, very important and they made me realize that farmers are not always bad guys and I think you cannot always put the things on them and say oh you can do this in this way…" (Participant-DTS). This also indicates that incorporating multiple perspectives enabled the participants to critically reflect on the dominant ways of seeing things (dominant perspectives) and question their own assumptions. Challenging perspectives is one of the critical phases of the transformative learning experience (Mezirow, 1978; Nerstrom, 2014) and participants in both cases mentioned experiencing this phase. Challenging perspectives is usually not a comfortable learning phase (Macintyre et al., 2020; Roberts, 2006) and therefore, exposure to diverse perspectives, where perspectives were exchanged and challenged, was uncomfortable for many FESS participants.

In both courses, the disorientation was provided through diverse perspectives, but exposure to these diverse perspectives, followed by discourse and critical reflection, required: (a) setting up a sustainability theme (content) in a particular situation (context); (b) providing opportunities for direct participation via DT tools in teams (process); (c) using digital tools to support the learning processes and environment; and (d) teaching team's support (facilitation). Providing diverse perspectives alone is not enough to ensure disorienting dilemmas leading to transformative learning experiences. For example, "Empathy Map" as one of the DT tools (process) was provided to the participants to extract unique insights from the perspectives of diverse stakeholders in their respective teams while working on the Miro boards (digital tool) (see Figs. 10 and 11). To use this tool, participants collected diverse perspectives (perspective) on the sustainability theme (content) in a particular context (context-Kashiwa no ha/Hude) via interviews, expert presentations, and past reports/literature. The teaching team explained the tool before participants used it and supported them when they asked for help, had questions, or needed prompts to initiate discussions. Hence, all six components of the DTP framework are essential to provide learning processes and environment conducive to transformative learning.

In both cases, the course design (DT toolkit) provided opportunities for discourse and critical reflection by incorporating all the components of the DTP framework, as discourse and critical reflection are crucial for transformative learning (Mezirow, 1997; Taylor, 2008). For instance, using Empathy Map (Figs. 10 and 11) as a DT tool required participants to engage in discourse within their teams and critically reflect on their own understanding of the diverse perspectives to establish a shared understanding or make new meaning in the form of empathy map to extract unique insights. Through DT as DTP, discourse is shaped in the processes of engagement and collective problem-solving, where participants challenge each other's perspectives and make meaning together. This kind of discourse excels the simple process of sharing information (Davis & Boulet, 2016; Vanasupa et al., 2014; Aboytes & Barth, 2020), and when participants, in both cases, were involved in this kind of discourse, they expressed critical examination of their own assumptions (perspectives) to make meaning collectively.

Exposure to diverse perspectives and engagement in the critical discourse around these perspectives allowed participants to be more open to diverse perspectives by understanding the differences (positions). Having an open mind, listening empathetically, avoiding judgments, and seeking common ground are necessary conditions to participate in discourse for transformative learning (Mezirow, 2003). Therefore, participants in both cases became more comfortable with their engagement in critical discourse within their teams as they moved through the stages of DT pedagogy which brought an increased sense of autonomy, confidence, and empowerment among the participants. Cranton (1994) also elucidated that learners' empowerment is vital for transformative learning. In HSE, this sense of agency and empowerment among learners is manifested as intentions to make a difference in their
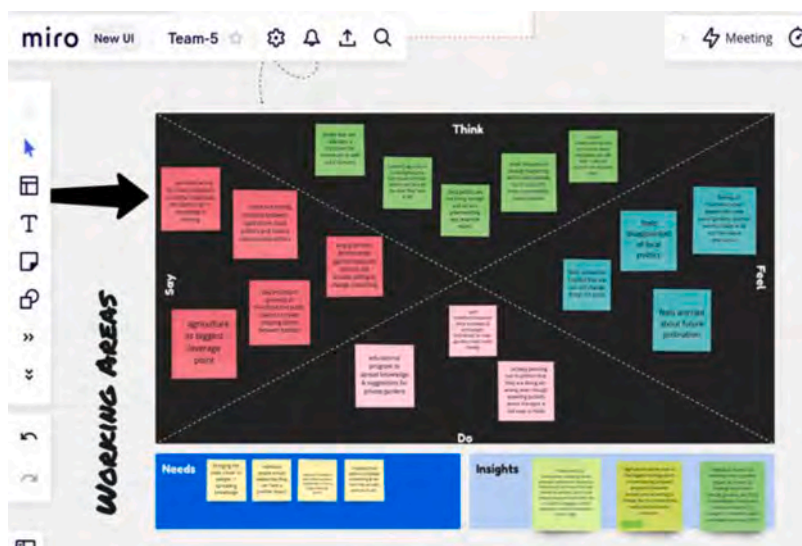

Fig. 11. . Team-5′s Empathy Map - DTS.

communities, promoting sustainable actions (Piasentin and Roberts, 2018; Probst et al., 2019). In FESS and DTS, participants enjoyed the process while working on real-world sustainability challenges; the process also empowered and motivated the participants to express the intention of staying engaged with the communities and implementing their projects in the respective communities (real-world) even after the course. For example, one of the participants from FESS expressed the desire to connect with local community members in Kashiwa no ha after working on the project on promoting internationalization and community building in Kashiwa no ha area. The participant said: "…now I feel more comfortable talking to people around this area, and I actively engage with them." (Participant-FESS). Another participant from DTS voiced the intention to organize a volunteer clean-up activity in Hude to conserve biodiversity in the area while saying: "I was thinking about this clean-up activity… we can spend a weekend in a nice hostel in Hude and I also thought about the combination with the school trips where school students can also join us…" (Participant-DTS).

Participants regarded Miro boards as a valuable and effective digital tool that guaranteed the visualization of information, ideas, and thinking processes. One of the critical principles of DT pedagogy is visualization, which proposes to make abstract ideas visible and tangible (Buhl et al., 2019). Participants were able to visualize their thinking process and see the thinking processes of others in the team through Miro boards which supported effective discourse and reflections.

Although participants in DTS engaged well in the process, they expressed that their engagement could have been better if they could visually see the landscape of Hude municipality. Some participants also suggested improving the context in the digital settings by providing visual aids like videos and clips captured by drones. Participants' experiences reveal that context and processes were better experienced in hybrid settings than digital settings as participants from FESS observed the area's landscape by visiting the area during the course.

7. Conclusion

The research concludes that DT as a DTP in HSE sets up the learning processes and environment conducive to transformative learning experiences by provoking disorienting dilemmas, discourse, and critical reflections. The research findings emphasize that DT pedagogy successfully incorporated all the six components of the DTP framework, including content, perspective, process, context, digital tools, and facilitation, in both cases (hybrid and digital settings; graduate and undergraduate level courses). All six components of the DTP framework are essential to encourage transformative learning experiences. The real world relevance and collaborative nature of the learning experiences encouraged the participants (in both cases) to indicate gaining confidence in their abilities to solve sustainability challenges in real world situations and express the intentions to apply their learnings in the real world. Hence, DT pedagogy can achieve the purpose of HSE by ensuring human development suited to achieve sustainable development. For educational practice, the study proposes that DT may bring transformative learning into practice in HSE in both hybrid and digital settings. Thus, DT can be used as a transformative pedagogy in a digital or hybrid learning approach without complex structural changes. This study contributes to the field of SE by providing an example of an effective, transformative pedagogy that can be used in HSE to nurture sustainability leaders. The research can offer concrete practice, pathways, and lessons for curriculum development to bring transformative learning into digital teaching practice in HSE.

The current research investigates DT as DTP in two different contexts, but it cannot be said that it has no relevance in other contexts as those in other contexts (or readers) can decide how DT as DTP can apply to their situation (case-inspired generalizations). Therefore, it will be useful to investigate and explore DT as DTP in other contexts. The research also recommends further investigation into capturing the transformative potential of DT as DTP by apprehending the transformative learning experiences using other (evaluative) frameworks.

Declaration of Competing Interest

The authors declare no conflict of interest in the current research.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijer.2022.101994.

References

Adomßent, M. (2016). Sustainability science and transdisciplinary education. In *Regional/Thematic Symposium on Broadening the Sustainability Science Approach in support of the 2030 Agenda for Sustainable Development, Berjaya Times Square Hotel.* https://en.unesco.org/sites/default/files/sussc_s2_panel_1_presentation_maikadomssent.pdf.

Archibald, M. M., Ambagtsheer, R. C., Casey, M. G., & Lawless, M. (2019). Using zoom videoconferencing for qualitative data collection: Perceptions and experiences of researchers and participants. *International Journal of Qualitative Methods, 18*, 1–8. https://doi.org/10.1177/1609406919874596

Avsec, S., & Ferk Savec, V. (2021). Pre-Service teachers' perceptions of, and experiences with, technology-Enhanced transformative learning towards education for sustainable development. *Sustainability, 13*(18), 10443. https://doi.org/10.3390/su131810443

Benson, J., & Dresdow, S. (2014). Design thinking: A fresh approach for transformative assessment practice. *Journal of Management Education, 38*(3), 436–461. https://doi.org/10.1177/1052562913507571

Berge, Z. L., Collins, M., & Dougherty, K. (2000). Design guidelines for web-based courses. In Z. L. Berge, M. Collins, & K. Dougherty (Eds.), *Instructional and cognitive impacts of web-based education* (pp. 32–40). Hershey: IGI Global. https://doi.org/10.4018/978-1-878289-59-9.ch002.

Birdman, J., Wiek, A., & Lang, D. J. (2021). Developing key competencies in sustainability through project-based learning in graduate sustainability programs. *International Journal of Sustainability in Higher Education.* https://doi.org/10.1108/IJSHE-12-2020-0506

Blackstock, K. L., & Carter, C. E. (2007). Operationalising sustainability science for a sustainability directive? Reflecting on three pilot projects. *Geographical Journal, 173*(4), 343–357. https://doi.org/10.1111/j.1475-4959.2007.00258.x

Boyatzis, R. E. (1998). Transforming *qualitative information: Thematic analysis and code development. Transforming qualitative information: Thematic analysis and code development.* Thousand Oaks CA: Sage Publications.

Braun, V., & Clarke, V. (2012). Thematic analysis. H. Cooper, P.M. Camic, D.L. Long, A.T. Panter, D. Rindskopf, & K.J. Sher. *APA handbooks in psychology®. APA handbook of research methods in psychology, vol. 2. research designs: Quantitative, qualitative, neuropsychological, and biological* (pp. 57–71). Washington DC: American Psychological Association. https://doi.org/10.1037/13620-004.

Brickell, G., & Herrington, J. (2006). Scaffolding learners in authentic, problem based e-learning environments: The Geography Challenge. *Australasian Journal of Educational Technology, 22*(4), 531–547. https://doi.org/10.14742/ajet.1284

Brown, T. (2009). Change by design: How design thinking transforms organizations and inspires innovation. *Change by design: How design thinking transforms organizations and inspires innovation.* New York: Harper Collins.

Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues, 8*(2), 5–21. https://doi.org/1511637.

Buhl, A., Schmidt-Keilich, M., Muster, V., Blazejewski, S., Schrader, U., Harrach, C., et al. (2019). Design thinking for sustainability: Why and how design thinking can foster sustainability-oriented innovation development. *Journal of Cleaner Production, 231*, 1248–1257. https://doi.org/10.1016/j.jclepro.2019.05.259

Burns, H. L. (2016). Learning sustainability leadership: An action research study of a graduate leadership course. *International Journal for the Scholarship of Teaching and Learning, 10*(2), 1–11.

Burns, H. (2009). *Education as sustainability: An action research study of the burns model of sustainability pedagogy.* Portland: Portland State University.

Burns, H. (2011). Teaching for transformation:(Re) designing sustainability courses based on ecological principles. *Journal of Sustainability Education, 2*, 1–15. http://archives.pdx.edu/ds/psu/9389.

Burns, H. L. (2015). Transformative sustainability pedagogy: Learning from ecological systems and indigenous wisdom. *Journal of Transformative Education, 13*(3), 259–276. https://doi.org/10.1177/1541344615584683

Caniglia, G., John, B., Bellina, L., Lang, D. J., Wiek, A., Cohmer, S., et al. (2018). The glocal curriculum: A model for transnational collaboration in higher education for sustainable development. *Journal of Cleaner Production, 171*, 368–376. https://doi.org/10.1016/j.jclepro.2017.09.207

Carolan, C., Davies, C. L., Crookes, P., McGhee, S., & Roxburgh, M. (2020). COVID 19: Disruptive impacts and transformative opportunities in undergraduate nurse education. *Nurse Education in Practice, 46*, Article 102807. https://dx.doi.org/10.1016%2Fj.nepr.2020.102807.

Choi, J. I., & Hannafin, M. (1995). Situated cognition and learning environments: Roles, structures, and implications for design. *Educational Technology Research and Development, 43*(2), 53–69. https://doi.org/10.1007/BF02300472

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning and instruction: Essays in honour of Robert Glaser* (pp. 453–494). Hillsdale, NJ: LEA.

Cortese, A. (2005). Learning principles for sustainability: Sustainability curriculum framework for curriculum development. *Second Nature: Education for Sustainability.* https://www.uwosh.edu/facstaff/barnhill/490-docs/readings/Second%20Nature%20-%20Education%20for%20Sustainability.pdf.

Creswell, J. W., & Creswell, J. D. (2017). Research design: Qualitative, quantitative, and mixed methods approaches. *Research design: Qualitative, quantitative, and mixed methods approaches.* Thousand Oaks CA: Sage Publications.

Dam, R., & Siang, T. (2018). What is design thinking and why is it so popular. *Interaction Design Foundation, 1–6.*

Davis, K., & Boulet, M. (2016). Transformations? Skilled change agents influencing organisational sustainability culture. *Australian Journal of Environmental Education, 32*(1), 109–123. https://doi.org/10.1017/aee.2015.51

Dixson, M. D. (2010). Creating effective student engagement in online courses: What do students find engaging? *Journal of the Scholarship of Teaching and Learning, 10*(2), 1–13. https://files.eric.ed.gov/fulltext/EJ890707.pdf.

Eldh, A. C., Årestedt, L., & Berterö, C. (2020). Quotations in qualitative studies: Reflections on constituents, custom, and purpose. *International Journal of Qualitative Methods, 19*, 1–6. https://doi.org/10.1177/1609406920969268

Elmassah, S., Biltagy, M., & Gamal, D. (2021). Framing the role of higher education in sustainable development: A case study analysis. *International Journal of Sustainability in Higher Education, 23*(2), 320–355. https://doi.org/10.1108/IJSHE-05-2020-0164

García-Morales, V. J., Garrido-Moreno, A., & Martín-Rojas, R. (2021). The transformation of higher education after the COVID disruption: Emerging challenges in an online learning scenario. *Frontiers in Psychology, 12*, 196. https://doi.org/10.3389/fpsyg.2021.616059

Greenfield, P. M. (1984). A theory of the teacher in the learning activities of everyday life. In B. Rogoff, & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 117–138). Cambridge, MA: Harvard University Press.

Gregory, S., & Bannister-Tyrrell, M. (2017). Digital learner presence and online teaching tools: Higher cognitive requirements of online learners for effective learning. *Research and Practice in Technology Enhanced Learning, 12*(1), 1–17. https://doi.org/10.1186/s41039-017-0059-3

Grunwald, A. (2004). Strategic knowledge for sustainable development: The need for reflexivity and learning at the interface between science and society. *International Journal of Foresight and Innovation Policy, 1*(1–2), 150–167.

Harley, S. (1993). Situated learning and classroom instruction. *Educational Technology, 33*(3), 46–51. https://www.jstor.org/stable/44427991.

Hemenway, T. (2000). Gaia's garden. *Gaia's garden.* White River Junction, VT: Chelsea Green.

Herrington, A., & Herrington, J. (2005). *Authentic learning environments in higher education.* Hershey: IGI Global.

Herrington, J. (2006). Authentic e-learning in higher education: Design principles for authentic learning environments and tasks. In *Proceedings of the E-Learn: World conference on E-Learning in corporate, government, healthcare, and higher education* (pp. 3164–3173). Association for the Advancement of Computing in Education (AACE).

Herrington, J., & Kervin, L. (2007). Authentic learning supported by technology: Ten suggestions and cases of integration in classrooms. *Educational Media International, 44*(3), 219–236. https://doi.org/10.1080/09523980701491666

Herrington, J., Oliver, R., & Reeves, T. C. (2003). Patterns of engagement in authentic online learning environments. *Australasian Journal of Educational Technology, 19*(1), 59–71. https://doi.org/10.14742/ajet.1701

Herrington, J., Reeves, T. C., & Oliver, R. (2014). Authentic learning environments. In J. Spector, M. Merrill, J. Elen, & M. Bishop (Eds.), *Handbook of research on educational communications and technology* (pp. 401–412). New York: Springer. https://doi.org/10.1007/978-1-4614-3185-5_32.

IBM. (2020). Design Thinking Activities and Tools – Enterprise Design Thinking *(n.d.).* Retrieved February 20, 2020, from https://www.ibm.com/design/thinking/page/toolkit.

Jonassen, D. H. (1993). The trouble with learning environments. *Educational Technology, 33*(1), 35–37. Retrieved November 16, 2021 from https://www.learntechlib.org/p/170916/.

Kaza, S. (1999). Liberation and compassion in environmental studies. In G. A. Smith, & D. R. Williams (Eds.), *Ecological education in action* (pp. 143–160). Albany, NY: State University of New York Press.

Kitano, M. K. (1997). A rationale and framework for course change. In M. K. Kitano, & A. I. Morey (Eds.), *Multicultural course transformation in higher education: A broader truth* (pp. 18–30). Needham Heights, MA: Allyn and Bacon.

Krishnamurthy, S. (2020). The future of business education: A commentary in the shadow of the Covid-19 pandemic. *Journal of Business Research, 117*, 1–5. https://doi.org/10.1016/j.jbusres.2020.05.034

Kuckartz, U., & Rädiker, S. (2019). *Analyzing qualitative data with Maxqda*. Cham: Springer. https://doi.org/10.1007/978-3-030-15671-8

Laiken, M. (2005). Authentic graduate education for personal and workplace transformation. In A. Herrington, & J. Herrington (Eds.), *Authentic learning environments in higher education* (pp. 15–33). Hershey: IGI Global.

Lawson, B. (2006). *How designers think*. Westfield NJ: Routledge. https://doi.org/10.4324/9780080454979

Leal Filho, W., Pallant, E., Enete, A., Richter, B., & Brandli, L. L. (2018). Planning and implementing sustainability in higher education institutions: An overview of the difficulties and potentials. *International Journal of Sustainable Development & World Ecology, 25*(8), 713–721. https://doi.org/10.1080/13504509.2018.1461707

Leblanc, T. (2009). Transdisciplinary design approach. P. Kotzé, W. Wong, J. Jorge, A. Dix & P.A. Silva. In *Creativity and HCI: From experience to design in education. ifip – international federation for information processing, 289*. Boston: Springer. https://doi.org/10.1007/978-0-387-89022-7_8.

IDEO. (2012). Design thinking for educators*, (*2nd ed.). Retrieved February 20, 2020, from http://designthinkingforeducators.com/.

Leuphana University . (2021). *Complimentary studies.*Retrieved April 20, 2021, from https://www.leuphana.de/en/college/study-program/complementary-studies-programme.html.

Leuphana University, (2021)., *Transdisciplinary case-studies, district of oldenburg.*Retrieved August 16, 2021, from https://www.leuphana.de/en/portals/leverage-points/transdisciplinary-case-studies/district-of-oldenburg-germany.html.

Li, N., Chan, D., Mao, Q., Hsu, K., & Fu, Z. (2018). Urban sustainability education: Challenges and pedagogical experiments. *Habitat International, 71*, 70–80. https://doi.org/10.1016/j.habitatint.2017.11.012

Liedtka, J. (2020). University of Virginia's Darden School of Business Coursera course: Design Thinking for Innovation.Retrieved May 5, 2020, from https://www.coursera.org/learn/uva-darden-design-thinking-innovation#syllabus.

Luka, I. (2014). Design thinking in pedagogy. *The Journal of Education, Culture, and Society, 5*(2), 63–74. https://doi.org/10.15503/jecs20142.63.74

Macintyre, T., Tassone, V. C., & Wals, A. E. (2020). Capturing transgressive learning in communities spiraling towards sustainability. *Sustainability, 12*(12), 1–20. https://doi.org/10.3390/su12124873

Marinoni, G., Van't Land, H., & Jensen, T. (2020). The impact of Covid-19 on higher education around the world. *IAU Global Survey Report*, 1–50. https://www.iau-aiu.net/IMG/pdf/iau_covid19_and_he_survey_report_final_may_2020.pdf.

Meena, M., & Rumao, P. (2021). Survey paper on effect of different tools developed for online learning education (Like blended teaching learning philosophy-TLP) in engineering education. *Journal of Engineering Education Transformations, 35*(SP), 78–84.

Melles, G., Anderson, N., Barrett, T., & Thompson-Whiteside, S. (2015). Problem finding through design thinking in education. *Inquiry-based learning for multidisciplinary programs: A conceptual and practical resource for educators (Innovations in higher education teaching and learning, vol. 3)*. Bingley: Emerald Group Publishing Limited. https://doi.org/10.1108/S2055-364120150000003027

Merriam, S. B. (1988). Case study research in education: A qualitative approach. *Case study research in education: A qualitative approach*. San Francisco: Jossey-Bass.

Meyers, S. A. (2008). Using transformative pedagogy when teaching online. *College Teaching, 56*(4), 219–224. https://doi.org/10.3200/CTCH.56.4.219-224

Mezirow, J. (1978). Perspective transformation. *Adult Education, 28*(2), 100–110. https://doi.org/10.1177/074171367802800202

Mezirow, J. (1990). How critical reflection triggers transformative learning. Associates. In J. Mezirow (Ed.), *Fostering critical reflection in adulthood: A guide to transformative and emancipatory learning* (pp. 1–20). San Fransisco: Jossey-Bass.

Mezirow, J. (1991). *Transformative dimensions of adult learning*. San Francisco: Jossey-Bass.

Mezirow, J. (1997). Transformative learning: Theory to practiceP. Cranton (Ed.), Transformative learning: Theory to practice. *Transformative Learning In Action: Insights from Practice - New Directions For Adult and Continuing Education (vol. 74, pp. 5–12)*.

Mezirow, J. (2000). *Learning as transformation: Critical perspectives on a theory in progress. The Jossey-Bass higher and adult education series*. San Fransisco: Jossey-Bass.

Mezirow, J. (2003). Transformative learning as discourse. *Journal of Transformative Education, 1*(1), 58–63. https://doi.org/10.1177/1541344603252172

Mino, T., Esteban, M., Asokan, V. A., Satanarachchi, N., Akiyama, T., Ikeda, I., et al. (2016). Philosophy of field methods in the GPSS-GLI program: Dealing with complexity to achieve resilience and sustainable societies. M. Esteban, T. Akiyama, C, Chen, I. Ikeda, & T. Mino (Eds.). *Sustainability science: Field methods and exercises* (pp. 3–19). Cham: Springer. https://doi.org/10.1007/978-3-319-32930-7_1.

Moore, J. (2005). Is higher education ready for transformative learning? A question explored in the study of sustainability. *Journal of Transformative Education, 3*(1), 76–91. https://doi.org/10.1177/1541344604270862

Munyai, K. (2016). Design Thinking: A Methodology towards Sustainable Problem Solving in Higher Education in South Africa. In *paper presented at International Conferences on Internet Technologies & Society (ITS), Education Technologies (ICEduTECH), and Sustainability, Technology and Education (STE)*. https://eric.ed.gov/?id=ED571612.

Murphy, M. P. (2020). COVID-19 and emergency eLearning: Consequences of the securitization of higher education for post-pandemic pedagogy. *Contemporary Security Policy, 41*(3), 492–505. https://doi.org/10.1080/13523260.2020.1761749

Nerstrom, N. (2014). An emerging model for transformative learning. In *Proceedings of the Adult education research conferenc*. Harrisburg: Kansas State University. https://newprairiepress.org/cgi/viewcontent.cgi?article=3329&context=aerc.

Nielsen, N. M. (2020). Problem-oriented project learning as a first year experience: A transformative pedagogy for entry level PPL. *Education Sciences, 10*(1), 1–17. https://doi.org/10.3390/educsci10010006

Norström, A. V., Cvitanovic, C., Löf, M. F., West, S., Wyborn, C., Balvanera, P., et al. (2020). Principles for knowledge co-production in sustainability research. *Nature Sustainability, 3*(3), 182–190. https://doi.org/10.1038/s41893-019-0448-2

Onuki, M., & Mino, T. (2009). Sustainability education and a new master's degree, the master of sustainability science: The Graduate Program in Sustainability Science (GPSS) at the University of Tokyo. *Sustainability Science, 4*(1), 55–59. https://doi.org/10.1007/s11625-009-0073-5

Orr, D. W. (1992). *Ecological literacy: Education and the transition to a postmodern world*. Albany: Suny Press.

Pearse, N. (2019). An illustration of deductive analysis in qualitative research. A. Stacey. In *Proceedings of the 18th European conference on research methodology for business and management studies (20-21 June 2019, Johannesburg, South Africa* (pp. 264–270). London: ACPI.

Piasentin, F. B., & Roberts, L. (2018). What elements in a sustainability course contribute to paradigm change and action competence? A study at Lincoln University, New Zealand. *Environmental Education Research, 24*(5), 694–715. https://doi.org/10.1080/13504622.2017.1321735

Plattner, H. (2010). Bootcamp bootleg. Institute of Design at Stanford. Retrieved February 6, 2020, from https://dschool.stanford.edu/resources/design-thinking-bootleg.

Plattner, H., Meinel, C., & Weinberg, U. (2009). *Design thinking: Innovationen Lernen-Ideenwelten öffnen. Mi-Wirtschaftsbuch-Verlag. Munich*. München: FinanzBuch Verlag GmbH.

Probst, L., Bardach, L., Kamusingize, D., Templer, N., Ogwali, H., Owamani, A., et al. (2019). A transformative university learning experience contributes to sustainability attitudes, skills and agency. *Journal of Cleaner Production, 232*, 648–656. https://doi.org/10.1016/j.jclepro.2019.05.395

Reimers, F., Schleicher, A., Saavedra, J., & Tuominen, S. (2020). Supporting the continuation of teaching and learning during the COVID-19 Pandemic. *OECD, 1*(1), 1–38. https://globaled.gse.harvard.edu/files/geii/files/supporting_the_continuation_of_teaching.pdf.

Riverdale Country School., & IDEO. (2011). Design thinking for educators toolkit. https://www.ideo.com/post/design-thinking-for-educators.

Roberts, N. (2006). Disorienting dilemmas: Their effects on learners, impact on performance, and implications for adult educators. In M. S. Plakhotnik, & S. M. Nielsen (Eds.), *Proceedings of the Fifth Annual College of Education Research Conference: Urban and International Education Section* (pp. 100–105). Miami: Florida International University. https://digitalcommons.fiu.edu/cgi/viewcontent.cgi?article=1249&context=sferc&httpsredir=1&referer=.

Savery, J., & Duffy, T. (1996). Aprendizaje basado en problemas: Un modelo instruccional y su marco constructivista. *Constructivist learning environments: Case studies in instructional design* (pp. 135–147). Englewood Cliffs, New Jersey: Educational technology publications, Inc.

Silverman, D. (2005). *Doing qualitative research: A practical handbook*. Thousand Oaks CA: Sage Publications.

Simon, H. A. (1969). *The sciences of the artificial* (1st Edition). Cambridge, MA: The MIT Press.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.

Stake, R.E. (.2003). Case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Strategies of Qualitative Inquiry*, (pp.134–164).

Sterling, S. (2001). *Sustainable education: Re-visioning learning and change*. Schumacher, England: Schumacher Briefings, 6 pounds https://www.greenbooks.co.uk/sustainable-education.

Sterling, S. (2004). The learning of ecology or the ecology of learning? In W. Scott, & S. Gough (Eds.), *Key issues in sustainable development and learning* (pp. 68–71). New York NY: Routledge.

Sterling, S. (2010). Learning for resilience, or the resilient learner? Towards a necessary reconciliation in a paradigm of sustainable education. *Environmental Education Research, 16*(5–6), 511–528. https://doi.org/10.1080/13504622.2010.505427

Taimur, S. (2020). Pedagogical taining for sustainability education. In W. Leal Filho, A.M. Azul, L. Brandli, P.G. Özuyar, & T. Wall (Eds.). *Quality education. Encyclopedia of the UN sustainable development goals* (pp. 611–621). Cham: Springer. https://doi.org/10.1007/978-3-319-95870-5_51.

Taimur, S., & Onuki, M. (2020). Effective implementation of sustainability education in higher education settings via transformative learning approach: Literature review and framework proposal. In S. Orakcı (Ed.), *Paradigm shifts in 21st century teaching and learning* (pp. 230–251). Hershey: IGI Global. https://doi.org/10.4018/978-1-7998-3146-4.ch015.

Talwar, S., Wiek, A., & Robinson, J. (2011). User engagement in sustainability research. *Science and Public Policy, 38*(5), 379–390. https://doi.org/10.3152/030234211x12960315267615

Taylor, E. W. (2008). Transformative learning theory. *New Directions for Adult & Continuing Education, 119*, 5–15. doi: 10.1002/ace.

Taylor, E. W. (2007). An update of transformative learning theory: A critical review of the empirical research (1999–2005). *International Journal of Lifelong Education, 26*(2), 173–191. https://doi.org/10.1080/02601370701219475

Thienen, J. V., Meinel, C., & Nicolai, C. (2014). How design thinking tools help to solve wicked problems. *Design thinking research* (pp. 97–102). Cham: Springer.

Tinsley, H. E., & Weiss, D. J. (1975). Interrater reliability and agreement of subjective judgments. *Journal of Counseling Psychology, 22*(4), 358–376. https://doi.org/10.1037/h0076640

Tschimmel, K., Loyens, D., Soares, J., Oraviita, T., Jacinto, A., Barroca, A. et al. (2017). *D-Think Toolkit. Design Thinking Applied to Education and Training*. ERASMUS+ and KA2 Strategic Partnerships Authors. https://urn.fi/URN:NBN:FI-fe202101293246.

UDCK. (2018)., *Outlines and Activities. Retrieved August 16, 2021, from*https://www.udck.jp/about/180410_UDCKpamphlet_en.pdf.

UNESCO. (2017). *Education for sustainable development goals: Learning objectives*. France: United Nations Educational, Scientific and Cultural Organization. available at: Http://unesdoc.unesco.org/images/0024/002474/247444e.pdf.

UNLEASH. (2019). *Activity Cards*, UNLEASH.

Vanasupa, L., Schlemer, L., Burton, R., Brogno, C., Hendrix, G., & MacDougall, N. (2014). Laying the foundation for transdisciplinary faculty collaborations: Actions for a sustainable future. *Sustainability, 6*(5), 2893–2928. https://doi.org/10.3390/su6052893

Wrigley, C., & Straker, K. (2015). Design thinking pedagogy: The educational design ladder. *Innovations in Education and Teaching International, 54*(4), 374–385. https://doi.org/10.1080/14703297.2015.1108214

Yin, R. K. (2009). *Case study research: Design and methods (Vol. 5)*. Thousand Oaks CA: Sage publications.