Integrating education for sustainable development into a sustainable-smart transdisciplinary learning framework[1]

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ABSTRACT

Education for Sustainable Development (ESD) has been gaining traction as a promising approach for addressing social challenges and driving positive change within society. The purpose of this article is to explore how ESD can be foregrounded to reframe and enrich an existing learning framework called the Interdisciplinary Collaborative Online Learning Framework (ICoL). The ICoL framework has been developed since 2020 using a Design-based Research methodology. Literature on ESD lacks exploration of practical implementation for interdisciplinary collaborative projects within communities. This article interrogates the question of how to integrate ESD within the ICoL learning framework. This study is explorative, and data are drawn from a review of the literature and student reflections. A qualitative, themed analysis of the data revealed a fifth learning design principle and a fourth structuring element towards a new learning framework, called the Sustainable-Smart Transdisciplinary Learning Framework.

Keywords: education for sustainable development, sustainable-smart, transdisciplinary learning, social digital innovation

INTRODUCTION AND BACKGROUND

Foregrounding sustainability within universities has become essential, especially under conditions of ever-growing scarcity of resources and the threat of human-made and environmental disasters. Higher education and universities are responsible for societal transformation (Žalėnienė & Pereira, 2021) and should be at the forefront of driving Education for Sustainable Development (ESD). The target is to enable a collaborative effort from all stakeholders in sustainable development initiatives, to foster responsible behaviour, and encourage individuals to actively participate in shaping a sustainable future. 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Bruntland, 1987: 66).

Due to the multitude of socio-eco-political demands being placed on universities, driving education for sustainable development (ESD) lacks momentum, particularly in the African context (Manteaw, 2012; Dipholo & Biao, 2013; Tikly, 2019). Literature on ESD is focussed on a top-down (institutional and

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educational policy level) but is limited at a bottom-up (community) level. This article attempts to bridge this gap by engaging the ESD approach to reframe and enrich an existing learning framework referred to as the Interdisciplinary Collaborative Online Learning Framework (ICoL) (van den Berg & Verster, 2022a).

Within the above context, we reflect on a longitudinal Design-Based Research (DBR) study to move towards future learning spaces where ESD becomes a central concept entangled in learning. The study commenced in 2020, where design principles from the ICoL framework are tested and refined in practical student projects. These projects are interdisciplinary among Information Systems and Urban and Regional Planning students at two universities in Cape Town, South Africa. The focus of the student projects is to explore community-based environmental challenges and develop innovative technological prototypes to solve these challenges.

This article commences with a review of relevant literature on the topic of ESD to find meaningful ways of embedding it in the learning framework by exploring key concepts that have emerged over the previous iterations. The current ICoL learning framework is discussed and applied in a review of the data from the second iteration of this DBR study to highlight the shortcomings. Recommendations to refine the framework are subsequently provided for the third iteration to develop a sustainable-smart transdisciplinary learning framework if offered as a conclusion.

LITERATURE REVIEW

Education for Sustainable Development

Education for Sustainable Development is a holistic approach to education that drives sustainable development from a social, economic and environmental point of view (Vilmala et al., 2022). The traditional function of universities, as knowledge institutions is, evolving due to the growing challenges related to sustainability coupled with the demands of massification, globalisation, marketisation, and digitisation (Rosak-Szyrocka et al., 2022). The implementation of ESD depends on implementing interdisciplinary projects that integrate sustainability principles among university staff and their local and wider communities. This research area is constantly advancing, and more research is needed to understand the full extent of the benefits and challenges of ESD.

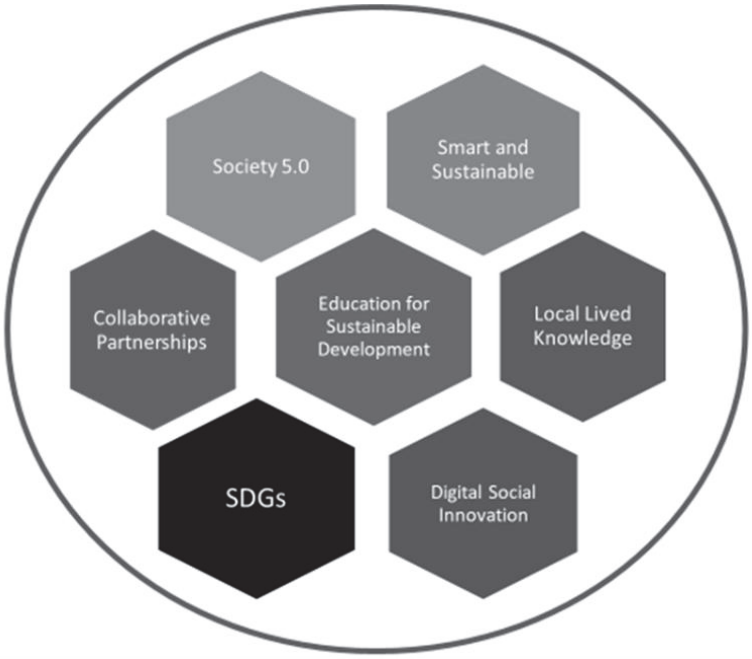
Some key insights on a roadmap to implement ESD include a focus on transformative action from learners and how individual learners are exposed to a sustainable future. Furthermore, structural change is required to address the fundamental causes of unsustainable development which requires an equilibrium between economic growth and sustainable development. ESD has to respond to the opportunities and challenges presented by a digital future whereby current problems may be alleviated whilst new challenges and risks will arise (UNESCO, 2020).

Incorporating ESD in learning environments includes a mix of different approaches that focus primarily on mainstreaming sustainability concerns in a more inclusive and participatory environment. Learners must become accustomed to the critical review of received knowledge and be supported by learner-led re-visioning activities. It is important to shift to networked learning over time within practical change projects that include cross-disciplinary approaches (O'Donoghue, Taylor & Venter, 2015). This can lead to the empowerment of learners 'with knowledge, skills, values and attitudes to take informed decisions and make responsible actions for environmental integrity, economic viability and a just society' (Leicht, Heiss & Byun, 2018: 7). To this end, ESD is often viewed as an 'action competence approach aiming at empowering students to take action to tackle with complex issues related to sustainable development' (Sinakou et al., 2019: 5994).

We interpret the holistic approach of ESD through several key concepts (see Figure 1), as it pertains to our disciplines of Information Systems and Urban Planning, and our context in the global South.

Figure 1:

Concepts to embed ESD in inter/transdisciplinary collaborative learning spaces



Society 5.0

The goal of Society 5.0 is to build an inclusive society that addresses societal constraints through emerging technologies. Whilst it is a new concept with limited application in Africa, the principles of leveraging technology for social good, inclusivity, and sustainable development align with the continent's goals and challenges (Ulmer & Wydra, 2020). The philosophic underpinning thereof of an equal and just society is incorporated to enable students to think about their future role as urban planning and information systems professionals dealing with our local and unique challenges in Africa. It strongly emphasises sustainable development and how to build the necessary capability and learning agility to successfully address the goals for sustainable development (Mishra, Thakur & Singh, 2022; Smuts & Van der Merwe, 2022).

The concept of Society 5.0 is to embed a human-centred approach to technology transformation taking the rapidly evolving technologies that Industry 4.0 employs for production within businesses and integrating them more deeply into the everyday lives of ordinary people (Gladden, 2019; Salgues (2018) provides insights by categorising Society 5.0's characteristics as the complete application of information and communication technology (ICTs) centred on common values that foreground community, people participation, sustainability and inclusivity. The goal is to build a society in which societal constraints are addressed by emerging technologies such as 5th-generation/6th-generation communication systems, IoT, AI, and big data, with other emerging communication, computing and sensing/actuation technologies into everyday life (Mishra et al., 2022).

Of special importance for this study is that Society 5.0 firstly emphasises community engagement and secondly that it is built on the ideals of sustainability. According to Kasinathan et al. (2022), Society 5.0

facilitates the accelerated progress of SDGs through the use of technologies. This provides an entry point in engaging with this concept in the higher education context and specifically how to incorporate this into individual learning spaces. The aim is that students need to be able to think critically, constructively and creatively under extreme conditions of rapid and severe changes.

A major contribution that incorporating Society 5.0 into education in general and learning environments specifically brings is its ability to integrate many complex elements such as the biophysical environment, society, economy (sustainability dimensions) and technology (smart). The philosophy of Society 5.0 instils a sense of social responsibility in students, inspiring them to actively engage in social change and contribute to achieving the SDGs.

Sustainable-smart innovations

Co-creating sustainable-smart innovations refer to the process of bringing together various stakeholders from academia, industry, government and the community, to jointly develop and implement sustainable and technology-enabled solutions. The focus of the study is on the application of digital technology particularly software applications to address challenges within marginalised communities. The emphasis is not solely on the technology itself but on the collaborative process with diverse stakeholders to co-create a more sustainable and equitable society, ensuring access to resources and opportunities for everyone's well-being. It is becoming increasingly important to design technology-enabled solutions that comply with constitutional and cultural values to limit potential damage to society (Helbing et al., 2021). Friedman and Hendry (2019) appeal for a value-sensitive design approach that values more than efficiency and economic growth in societies. Technology solutions should advance a human-centred society that balances economic progress with the resolution of social issues (Mishra et al., 2022). Aspects such as environmental conditions and health, safety and security, human dignity, well-being and happiness, privacy and self-determination (autonomy, sovereignty, freedom), fairness, equality, justice, consensus, peace, solidarity, sustainability, and resilience, all need to be considered (Friedman & Hendry, 2019; Helbing et al., 2021).

Sustainable-smart innovations emphasise a shift to Society 5.0 as mentioned above where innovations benefit all parties involved, whether they are consumers, workers, investors, the environment, or society (Mishra et al., 2022). This approach emphasises collaboration, active engagement, and co-creation of knowledge and solutions among stakeholders to achieve sustainable development goals. Projects that are linked to the community enable students to appreciate the impact of their discipline in local and global social contexts hence enabling high-impact learning (Strachan et al., 2019).

'Street-smart' local (lived) knowledge

Local knowledge or local knowing, in the context of this paper, refers to the know-how derived from the day-to-day lived realities of community members. In the rapidly changing social context of informal settlements in Cape Town, South Africa, this understanding of local (lived) knowledge does not necessarily refer to the traditions and cultural knowledge or indigenous knowledge (Antweiler, 1998: 469) that is typically associated with literature with this concept. Here we are referring to a 'knowledge-for-survival' that is learned at a fast pace and on the streets of informal settlements.

One of the key principles of ESD is the recognition of the value of local lived knowledge by valuing the intimate understanding that local communities often have of their environment and the challenges they face, and that this knowledge should be used to inform and guide sustainable development efforts (EUA,

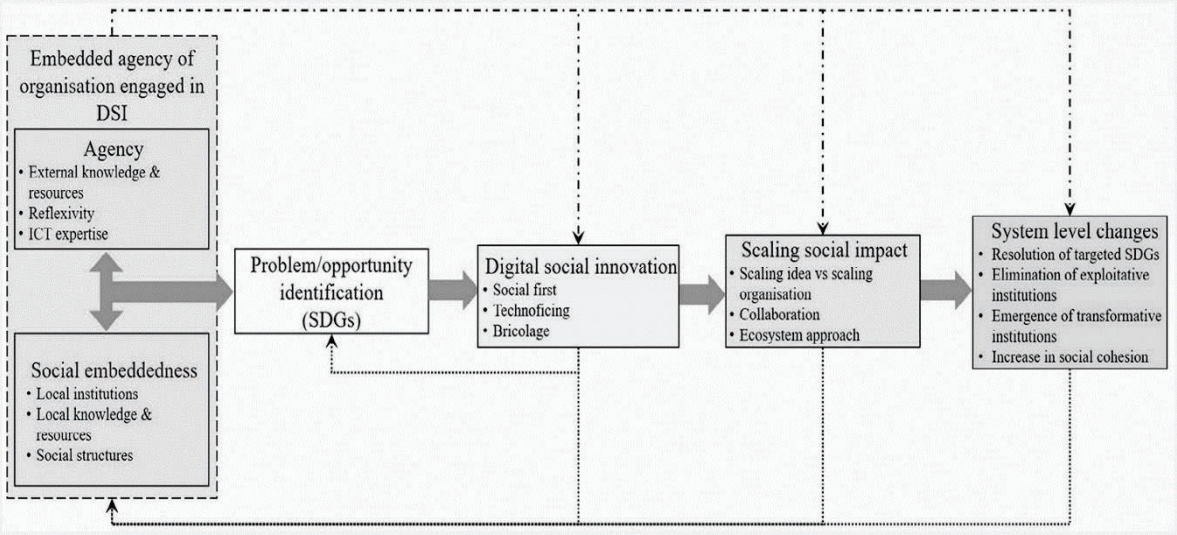
2021). There are numerous examples of local lived knowledge providing valuable insights and practical solutions for sustainable development challenges, especially in the non-governmental sector (NGO) (Hill et al., 2020). In such examples, local communities are involved in the identification, design and implementation of solutions to ensure that such solutions are tailored to the unique context and are more likely to be adopted and used effectively. We consider ESD as a way of integrating street-smart local (lived) knowledge into the mainstream learning spaces of higher education as one of the fundamental, but untapped, knowledge resources. ESD encourages active community engagement, and incorporating local knowledge can strengthen the connection between education and community development (Zidny, Sjöström & Eilks, 2020).

Digital social innovation

Digital social innovation (DSI) has been gaining attention in recent years as a promising approach for addressing social challenges and driving positive change within society. The digital dimension is the integration of emerging technologies in services to society. The social dimension needs to be the focal point and not the technology. The innovations should provide solutions that are more effective, sustainable and ethically adequate than those that are in place today (Serpa & Ferreira, 2019). DSI applies to projects that use digital technologies in conjunction with community engagement and collaboration, co-creation strategies and bottom-up approaches to address societal needs. At its core, DSI leverage digital technologies to generate positive social impacts, the aim is to explore innovative, effective and sustainable solutions to pressing societal challenges, for example, those listed in sustainable development goals (SDGs) (Qureshi, Pan & Zheng, 2021). However, in comparison to the use of ICTs for commercial use, digital transformation in the social space has been less dramatic, particularly in solving wicked social problems as identified under the SDGs (ibid., 2021). An overview of the process is illustrated in Figure 2.

Figure 2:

Process of digital social innovation



Qureshi et al. (2021)

As shown in Figure 2, DSI emphasises the importance of agency and social embeddedness by prioritising 'social issues over technological finesse' or 'pursuit of social objectives using a technology that is good

enough and appropriate for the purpose outreach to collaborate in the co-creation of solutions' (Qureshi et al., 2021: 654). This position is shared by ESD with its human/people-centred approach where social challenges are the drivers and not the technological solutions.

The sustainable development goals

The 17 SDGs were designed by considering a holistic view of sustainable development to benefit humanity and the ecosystem (United Nations, 2015). They involve the elements of human development, the economy, technology, resources, and environmental changes integrated into the path of sustainability. They are indeed complicated goals to achieve, and the uncertainties involved are unprecedented and cannot be quantified (Kasinathan et al., 2022). To realise their potential, in recent years a shift has occurred that emphasises the SDGs not only as global initiatives but rather as focussing on their localising potential (Jiménez-Aceituno et al., 2020; Moallemi et al., 2020). The localising potential has been the focus of the longitudinal student project that this paper draws from (van den Berg & Verster, 2020; 2022).

The impact of universities on the SDGs requires collaborative efforts between local higher education institutions and securing funding for community-oriented research, interdisciplinary research and outreach activities that facilitate the dissemination of diverse pedagogical approaches and influence broader public opinions (Rosak-Szyrocka et al., 2022). Furthermore, Žalėnienė and Pereira (2021), emphasise the importance of effective management and governance practices that incorporate SDGs principles into university operations; and cross-sectoral dialogues, showcasing an institutional commitment to the SDGs, and affirming public dedication (Žalėnienė & Pereira, 2021). A comprehensive sustainability education should prioritise a thorough understanding of the intricate interplay between social, economic, and environmental systems; recognition of the inherent interdependence of these systems for the realisation of a sustainable world; and an appreciation for the diversity of perspectives and strategies in addressing complex challenges (Wheeler, Hesselink & Goldstein, 2015). Thus, tailored curricula are indispensable to ensure effective learning about the SDGs.

Our focus is on SDG 11 (sustainable cities and communities) (United Nations, 2015) as the initial entry point for the student projects. However, it is emphasised that there needs to be a deep awareness of the interrelated nature of the SDGs and that none of them can and should be considered in isolation. This interrelated nature of the SDGs provides both an opportunity and an obstacle in learning spaces, the opportunity for students to negotiate real-world problems but with the complexity and uncertainty that this presents. This requires continuous awareness of the fine balance between powerful learning versus potential learning inertia.

Collaborative partnerships

The growing urgency to address the future of our societies and planet requires collaborative partnerships that co-create sustainable solutions whilst enabling the equilibrium between ecological, economic and social concerns (EAU, 2021). This complex endeavour calls for an inter/transdisciplinary focus to circumvent the narrow lenses of disciplinary boundaries. The application of a triple or quintuple helix approach can integrate different perspectives to set the stage for sustainability priorities and considerations (Carayannis & Morawska-Jancelewicz, 2021). In higher education for sustainability, this implies designing new sustainability curricula and programmes that position learning to collaborate as a key objective (Freeth & Caniglia, 2020; Tietjen et al., 2023). Creating a learning environment that foregrounds collaboration and interdisciplinary partnerships is complex. In the design and facilitation of the learning environment, it is crucial to expose learners to the challenges that can provoke discomfort

in interdisciplinary teams. When the challenges experienced in and among groups override the benefits it can compromise the viability of interdisciplinary collaboration (Freeth & Canglia, 2020). This requires constant monitoring of group dynamics and assistance to students in the navigation of group dynamics, interpersonal relationships and community engagement. Managing group work is complex in itself more so within interdisciplinary and transdisciplinary teams.

The next section describes the Interdisciplinary Collaborative Online Learning (ICoL) framework designed to facilitate interdisciplinary collaborative learning environments.

The ICoL framework

The Interdisciplinary Collaborative Online Learning (ICoL) framework has gone through three development phases since 2020. The first-generation framework was based on a pilot study that focused attention on agency in communities and resulted in four design principles: relationality, reflexivity, responsiveness and recognition (van den Berg & Verster, 2020). The second-generation framework developed the four design principles as pedagogical propositions and proposed an enriched understanding of each by suggesting sub-principles (Verster & van den Berg, 2021). The third-generation framework saw a return to theory in the form of sociomateriality and combined it with the concept of Future Learning Spaces (FLS). Enriching the third-generation framework with the student experience resulted in the emergence of four redefined design principles for the complex interdisciplinary, online learning space, namely: (i) context-sensitive learning experiences, (ii) co-construct knowledge, (iii) socio-technical and socio-cultural entanglements and (iv) relationality and agency (van den Berg & Verster, 2022b).

During the engagement with sociomateriality and FLS, three elements, namely pedagogy, space-time activities and technology, that can be considered as providing structure to the learning space emerged. Simplified, pedagogy incorporates the approach to collaborative, interdisciplinary learning and how this applies to the different design principles. The incorporation of space-time is emphasised by Tietjen et al. (2023), as an important element because it is not only where learning occurs but also when. Our definition of space-time activities refers to the space (virtual and/or in person, campus and/or site-community, formal/informal) and time (pacing, synchronous and asynchronous, class time and out of class time, time on different activities) and the specifics and practicalities of learning activities. For each design principle, examples are provided in the ICoL framework for potential technology applications, methods and programmes that can be utilised. Figure 3 provides a high-level breakdown of the design principles and structural elements. Figure 4 provides further detail on the application of each structuring element.

Figure 3:

Design Principles and Structure Elements

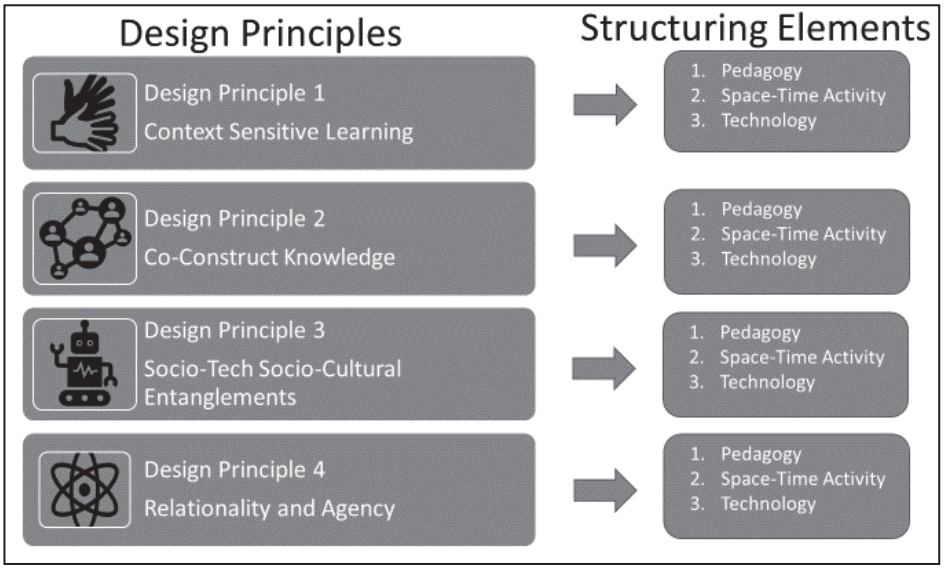
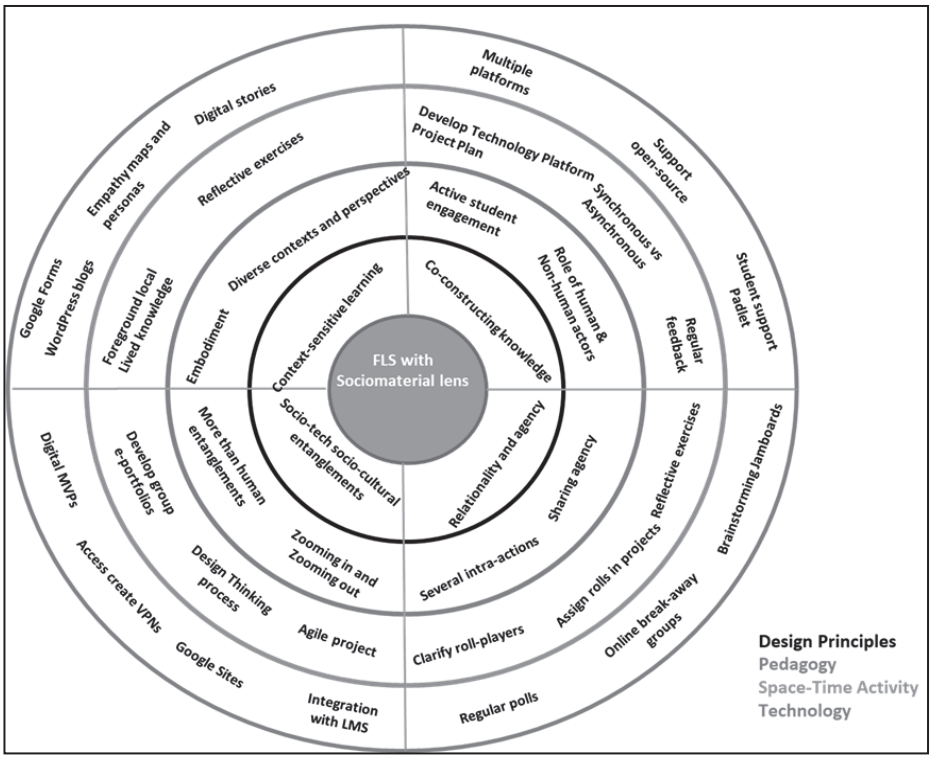


Figure 4:

The ICoL Framework



van den Berg (2022a)

As seen in Figure 4, the structuring elements for each design principle are depicted to first show the pedagogy followed by proposed space-time activities and examples of the application of technology in

the outer rim.

RESEARCH METHODOLOGY

The research is taking place within the broader design science paradigm by applying a Design-Based Research (DBR) approach. In a DBR study, the researchers will first gain an in-depth understanding of a problem before any prototype solution is designed and tested (Mckenney & Reeves, 2020). DBR differs from other types of scientific inquiry because it simultaneously develops both theoretical insights and practical solutions, together with stakeholders within authentic settings (ibid., 2020). This study has developed both theory and practical application within an iterative process of testing and refining the design principles and structuring elements as depicted in Figure 4. The goal is to solve complex real-world problems in authentic situations by cycles of analysis, design, development, evaluation and redesign. The design is validated via practical use within iterative cycles that confirm findings and align theory, design and practice (de Villiers & Harpur, 2013).

A DBR study is longitudinal and consists of a collection of sub-studies that are reported separately. The purpose is to further refine the design and test this in the following iteration to finalise the learning framework. This study applies a four-phase method as espoused by Reeves (2006):

Phase 1: Analysis of practical problems by researchers and other stakeholders in collaboration as well as a review of the literature.

Phase 2: Development of solutions informed by existing design principles and technology interventions.

Phase 3: Iterative cycles of testing and refining of draft design principles within practical settings.

Phase 4: Reflection to produce Design Principles and enhance solution implementation.

The study is currently in Phase 3 and two iterations have been completed in 2021 and 2022 with a third and final iteration planned for 2023.

The study took place among academics and students from two universities in Cape Town, South Africa. Participants included 30 students from the Honours group in Information Systems (IS) and 24 students from the Advanced Diploma in Urban and Regional Planning (URP) during the second iteration in 2022. The group project was part of the overall learning outcomes and assessments of both modules and permission was obtained from students to have their findings and reflections included in the data. Both universities also obtained ethical approval for the overall study.

Students' comments were collected through a structured questionnaire that consisted of 25 closed and open-ended questions. The questionnaire was made available to students via Google Forms. A total of 51 responses were received. The questionnaire was structured to test the design principles and structural elements of the ICoL framework. The responses were analysed via a thematic analysis of each theme within the framework.

DISCUSSION: TOWARDS THE SUSTAINABLE-SMART TRANSDISCIPLINARY LEARNING FRAMEWORK

In this section, the four design principles implemented during the second iteration are presented. In the review of each design principle, a breakdown of the three structuring elements, namely pedagogy, space-time activity and the use of technology are analysed according to the evidence from the data. The objective of this section is to review the findings to identify the limitations in the current ICoL framework and to apply the key findings from the review of the literature coupled with student feedback to refine the framework further.

Design principle 1: context-sensitive learning

This design principle calls for the creation of immersive context-sensitive learning experiences by incorporating different interactive tools to open up the learning space to divergent viewpoints and cultural perspectives about problems in communities.

Pedagogy

The pedagogical drivers that underpin this design principle were developed in the previous iteration of the study and tested and refined in this iteration. They include 'embodiment' and 'awareness of diverse contexts and perspectives'. Embodiment recognises the continuous reconfiguration of social and material systems where students are exposed to the movement across physical and virtual spaces to enable them to tap into their own local lived (embodied) knowledge in the learning activities we design.

The COVID-19 pandemic presented the challenge that all activities had to be moved online and the benefits of a more fluid blended environment could not be explored. In a review of the impact, students were asked to reflect on whether they felt they could represent themselves in virtual spaces and the majority, 73%, felt that they could. The obstacles in a fully online environment that were highlighted included, for example:

> Taking in content via online learning is great, however, class discussions, debates etc, where most of the learning generally takes place, are lost. I also believe that this could have contributed to the team's misunderstanding/misinterpreting direction.

> Part of my personality can't be represented in online learning. This means that a key part of myself is not displayed to my classmates and lecturers.

In a review of students' perception of 'awareness of diverse contexts and perspectives', the majority felt that the experience of working in the interdisciplinary group assisted them in shifting their thinking. Some examples include:

> The different perspectives influenced my learning by enabling me to view situations from other people's positions and to consider other people's views, experiences and beliefs. This provided me with a deeper understanding and empathy which decreases prejudice, judgment, and conflict, given our problem statement was based on homeless people.

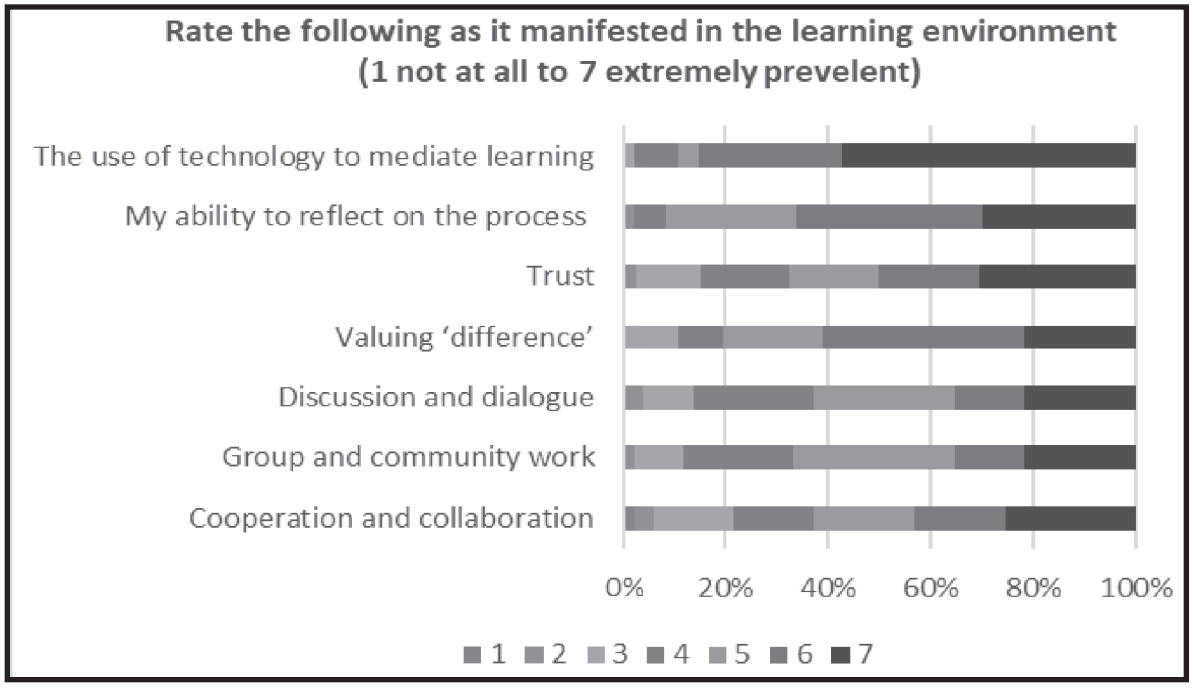
> A lot of the time I would view an answer one way but a group member who was different from me would help me to view things from a different perspective because of their personal experiences and background.

Space-Time Activities

A review of the perception of students regarding activities to stimulate context-sensitive learning is presented in Figure 5. It was essential to enable space and time for reflection on the learning as well as bringing in the students' local lived knowledge.

Figure 5:

Space-Time Activities for Context-Sensitive Learning



Students were asked to rank certain aspects that manifested in the learning on a scale from 1 to 7. The prevalence of an online learning environment emphasised the importance of technology as seen in Figure 5. It will be important to test this again in iteration 3 to determine the importance and also to ensure that an enabling environment for blended learning is created. The ability to reflect was prevalent, however, this was only requested at certain intervals during the project. In future iterations regular reflexive exercises and feedback on the process is required.

It is envisaged that more time will be spent actively working within the community in iteration 3 as we move to a blended learning environment with a focus on one specific area in Cape Town where the projects will be executed. A focus on more discussion and dialogue among the teams will also have to be strengthened.

Technology

The use of an online platform will continue as this proved to be very useful for cooperation among the groups. Students found this helpful:

> Google Docs was an excellent collaborative platform whereby my group was able to consistently share our findings.

The application of digital stories to show the problem from the communities' perspectives worked well and most groups found this to be a very useful tool to foreground the local lived knowledge residing within their communities:

> My biggest learning surprise during the project was on Personas and Digital stories. I never thought that we will get a chance to engage with the community and interview them, and shared the issues that they experienced in their communities. I am also surprised by the skills that I got already from this project like creating Digital stories and designing prototypes.

Design principle 2: co-construct knowledge

This principle focuses attention on the importance of considering all the role players (human and nonhuman) and their contribution to knowledge creation and developing relevant solutions. Co-constructing knowledge is not a simple feat and one that needs very careful and deliberate pedagogical, activity and technological decisions.

Pedagogy

It is important to ensure that there are opportunities for differing personality types to feel comfortable in the learning space to the point where they can freely contribute. The following student response made us aware of this issue:

> Working with people of different personalities was my biggest surprise. In my mind I did not think that introverts can work effectively with extroverts, to top it all when I heard that IS students are going to work with URP, I only thought of chaos and people misunderstanding each other. That worked out differently for me, the project was carried out effectively despite different personalities, backgrounds and different fields of study.

A further issue that shapes our pedagogical decisions is to be explicit in the value of bringing the disciplines of IS and URP together. The following student reflections show how students come to realise and value the contribution of each discipline through specific disciplinary knowledge, skills and values.

> My biggest learning surprise during this project was thinking the two disciplines, information systems, and urban & regional planning could never be linked. Secondly, acknowledging that different perspectives can help people to come up with great ideas to incorporate everyone that is affected.

> I underestimated the benefits that a different discipline could bring to your learning and how it could improve your knowledge.

We should map the knowledge areas that each of these disciplines, separately contribute to responding to the community problem (interdisciplinary) and then how we create new knowledge that is not attributed to only one discipline (transdisciplinary). This is an important shift to make in the enriched learning framework.

Space-time activities

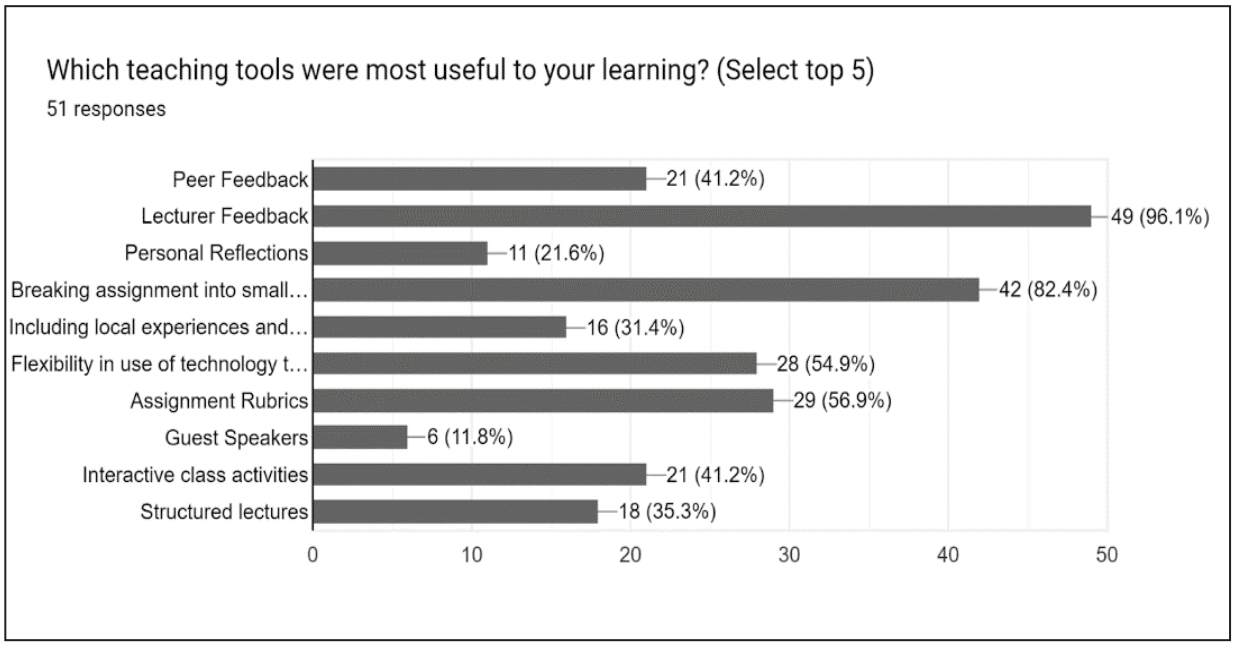
One of the realisations that emerged from the data, was the lack of project management by the students to assign roles and responsibilities. In the next iteration, this should be incorporated into a Code of Conduct

that will guide disciplinary and personal values, principles and ethics as well as the roles and responsibilities.

> We did not establish a group leader in our group project. It made it a bit more complex because no one would delegate work equally to the group members and others felt like they were putting in so much more work and effort than others.

A further essential consideration for co-constructing knowledge is ensuring opportunities for all voices to be heard and considered. As such a level of freedom should be allowed for student groups to negotiate their own choice of group engagement strategy, digital platforms, meeting times and places. We found one of the most valued lecturer activities to be feedback (Figure 6). Unfortunately, peer feedback scored very low, and this will have to be addressed in the next iteration as we value peer learning and need to scaffold it more constructively into the learning activities.

Figure 6:
The usefulness of teaching and learning tools available to the student groups

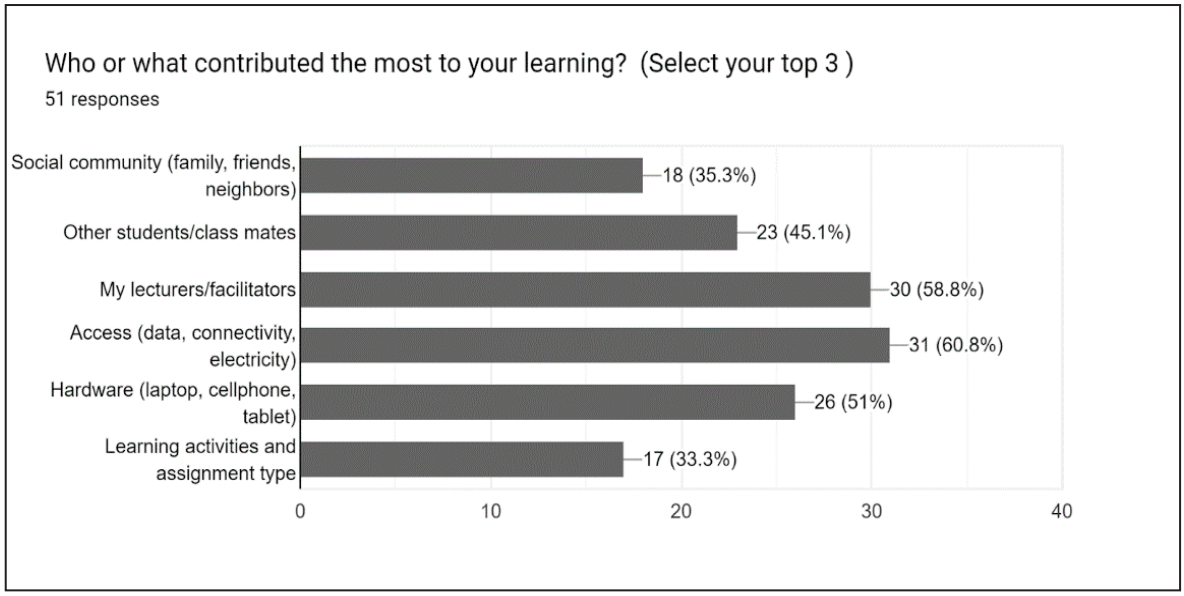


A serious concern as highlighted by Figure 6, is the seemingly meaningless activity of 'personal reflections'. This is concerning especially because we associate critical thinking abilities with being a reflective young professional. In the next iteration, the value of reflections will be emphasised and practised to upskill students in the art of critical reflection.

Technology

Technology was the most important enabler for the students to co-construct knowledge. This is clearly indicated in Figure 7 with two of the top three rated elements being 'access' and 'technology hardware'. Students thus rely heavily on technology to contribute to their groups, and it would be worth watching how this issue shifts in iteration 3 with the move from a fully online to a blended learning space.

Figure 7:
Who (human) or what (nonhuman) contributed most during this project?



We found it encouraging that students, although reliant on technology within the online learning space, also realised the value of collaboration as per the following student reflection:

> There are several valuable lessons I learnt through collaborative group work, but perhaps the most essential is that it is not about technology or developing a strong project plan, it is about being able to work with very diverse individuals.

Design Principle 3: socio-technical and socio-cultural entanglement

This design principle incorporates the intra-action between the human and technology (socio-technical) and the complexities within the human and their socio-economic-cultural settings. Both forms of entanglement highlight the reciprocal relationships between humans, culture and technology, and how they co-create and co-constitute each other. It is important to recognise the emergence of knowledge and agency in a learning design that allows for matters of space, time, different digital tools and other artefacts to co-evolve.

Pedagogy

The pedagogy focuses on acknowledging the more than human entanglements within the space as well as a process of zooming in and out from the bigger macro environment to the micro-level activities (Nicolini, 2009). Zooming out calls for a deeper analysis of the macro-level such as the larger social, political, and technological systems that shape and are shaped by them and zooming in to the space-time activities related to the specific interactions and practices of individuals (Tietjen et al., 2023). The design of the learning environment further needs to emphasise the importance of 'more-than-human entanglements' that stresses the interconnected relationships between human and non-human actors within the system. This allows for a deepened, interconnected, reciprocal relationship between students, facilitators, community members, technology, the environment and other learning objects to co-create artefacts to recognise agency.

> My biggest surprise was how amazingly intertwined different professions can be in pursuit of eradicating environmental problems.

> How technology and Planning can integrate, I learnt a lot about how technology can help fix planning problems in society.

Space-time activities

In the design of the activities, groups were tasked to create an e-portfolio that included the entire project, and it became a 'living environment' of interaction and collaboration. By incorporating a design-thinking methodology, students were guided to explore the problem from different lenses to develop their capability to continually change and adapt their thinking. A further consideration is to provide the opportunity for groups to recalibrate, pivot or change. The project follows an Agile methodology with short sprints to accommodate change and flexibility with a focus on the process and not the outcome.

> I was not familiar with google docs before the assignment so I learnt a lot from also how to develop digital stories and prototypes and that you can change if something is not working.

Technology

In the design of technology, it is important to enable students to work anywhere and at different times to integrate the socio-technical environment. This is prevalent in a learning environment where you work with students from marginalised communities. Access through Virtual Private Networks (VPNs), open source and integration with the university's LMS is required.

> One constraint that prevented me from attending meetings was Load Shedding. However, there were always alternatives. Someone from the group would update the rest of us via WhatsApp Message.

> Although everything was fast-paced, I did not struggle to play an active role in my group. Through the use of Google Meets and WhatsApp, I was always present.

Design Principle 4: relationality and agency

ESD as well as the key concepts we draw from position society and communities at the centre of both education and the current and future role of technology (see section 2). It is strongly human-centred and as such recognises the power dynamics that exist. For us to engage with power dynamics within the learning space, we focus on recognising relationality and agency.

Pedagogy

Numerous conflicting experiences were captured in the reflections in the previous examples, and this will need to be addressed in iteration 3. Similar to the issue being raised under design principle 2, it is clear that a need exists to be explicit about the value being added by each discipline separately and what the potential gains are when the disciplines co-create knowledge. This has a direct impact on the level of empowerment an individual student or group experience and as such impact their level of agency. Problems expressed by students are for example:

> My biggest surprise is that people don't take my profession seriously. There were parts that a planner should know what to do and how to solve things, but we were being questioned and

> corrected on whether we are doing the right thing and whether our ideas are valid enough or not.
>
> Consensus becomes a huge constraint in a group because everybody wants their opinion to be heard even though it does not speak to the problem at hand.
>
> There were only two active planners, and the majority were IS students who knew each other. I felt unheard and dismissed at times.

Space-time activities

Giving agency to the community for whom you are trying to support is a challenge one can only appreciate when experiencing it first-hand. This is recognised by a student in the following reflection:

> My biggest surprise with this project was just how "difficult" it is to include the people whose problem you're trying to solve from the conception stages right up to the making of your prototype even though this is the best way to get inclusive results.

This level of realisation boasts well for the learning objective of developing abilities to collaborate with complex role players.

Technology

Students were very aware of the shortcoming of agency and its associated sense of responsibility within the online learning space. The technological shortcomings, as can be seen from the student reflections, were accentuated as 'silent online', 'misunderstanding and poor communications in the online environment', 'lazy online' and 'loadshedding (power blackouts)'

> I dislike the fact that people would casually stay silent online, especially when questions are asked or simply not trying to come up with an idea or say something at all.
>
> During online environments, there are a lot of misunderstandings that sometimes lead to serious arguments and people are very lazy online and make excuses about connectivity issues.
>
> My group had very poor communication. I believe that if it was face-to-face things would have been different. Some of the group members were forever busy during the assignment, I feel like some people take advantage just because things are done online and just decide to be busy and nowhere to be found. Load shedding also caused big havoc in the online environment.

The next iteration of this project would have to respond to the above concerns as technology is a double-edged sword where it can provide ample access and connectivity amongst group members but also act as a screen behind which responsibilities and contributions can be hidden.

RECOMMENDATIONS: THE SUSTAINABLE-SMART TRANSDISCIPLINARY LEARNING FRAMEWORK

The culmination of the above engagement with literature and student reflections on iteration 2 of the student project is three distinct shifts to the learning framework:

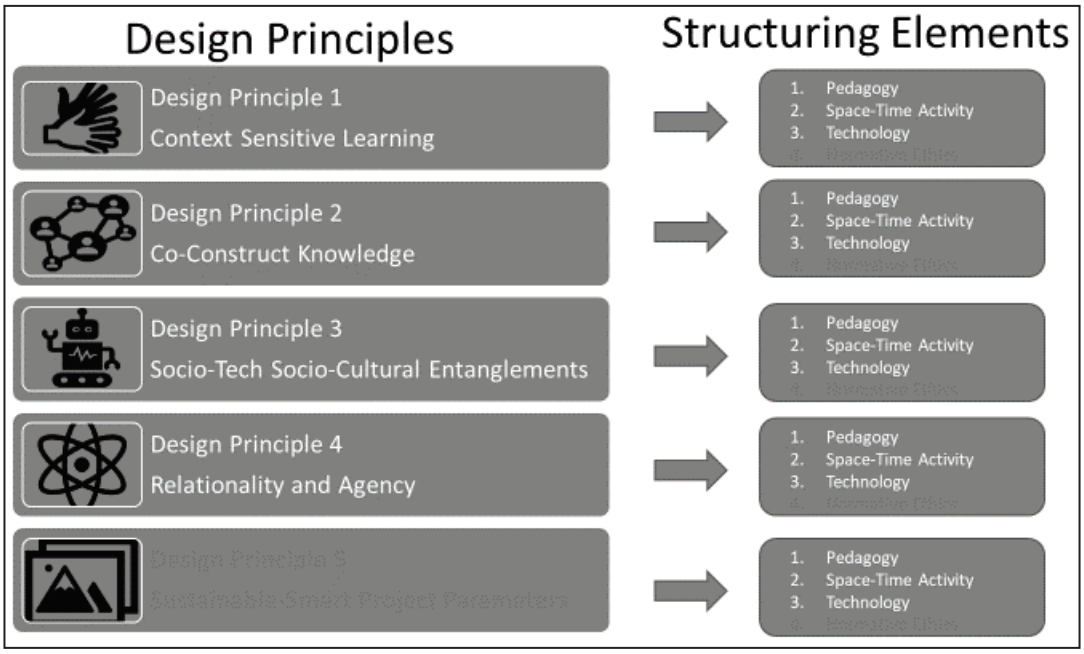
Shift 1: from an interdisciplinary learning space to a transdisciplinary space where students can engage with the value-adding abilities of transdisciplinary work. Fam et al. (2020) caution about the tension between disciplinary know-how and transdisciplinary knowledge, skills and values. Careful planning is needed in iteration 3 to negotiate and accommodate this complexity.

Shift 2: from an online learning space to a blended community-based learning space. As a result of the lifting of COVID-19 restrictions, it is possible to allow students both on campus and in communities. We have decided to focus our efforts on only one community (Dunoon/Potsdam Informal Settlement, in Cape Town, South Africa) and not spread our work amongst numerous communities to which our students had access.

Shift 3: this shift encapsulates the proposal of a new design principle as well as a new structuring element for the learning framework. The design principle, 'Sustainable-Smart Parameters' focuses attention on framing the student project within the sustainable-smart discourse where sustainability drives technology-enabled solutions. Sustainable-smart parameters are thus the fifth design principle that frames pedagogical, space-time activities and technology decisions made before, during and after the learning activity. The new structuring element, 'Normative Ethics', is understood to be referring to those issues that shape and influence one's ethical behaviour or the 'social ought to, thus what is acceptable in both the individual and the collective sphere. The social ought to transcend the professional space to also include the student's role as a responsible local and global citizen.

Figure 8:

The enriched learning framework with the addition of Sustainable-Smart Parameters as a new design principle and Normative Ethics as an additional structuring element



CONCLUSION

The article reviews the possibilities of embedding ESD to improve an existing learning framework developed in a DBR study that commenced in 2020. The purpose is to enrich current literature by contextualising ESD in a learning environment that foregrounds interdisciplinary collaborative learning within universities. The discussion incorporates a review of Society 5.0 through smart and sustainable designs that utilise local lived knowledge to design digital social innovations in collaborative partnerships that foreground the SDGs.

In the article, the design principles and structuring elements of the current ICoL framework are tested and refined through a review of the data from the second iteration. The aim is to develop theory and practical applications to enhance the ICoL framework to incorporate ESD.

Recommendations include a shift to a transdisciplinary space in the student project by actively engaging with multiple stakeholders within a community in Cape Town. This will be accomplished through the shift from an online to a blended learning approach. The third recommendation is to include an additional design principle to encapsulate specific sustainable-smart project parameters and to include an additional structuring element that features normative ethics within the learning framework. These changes will be tested and refined in the third and final iteration in 2023 to develop the sustainable-smart transdisciplinary learning framework.

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