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Bridging Local Realities and Global Goals: Exploring Student-Led Sustainable-Smart Innovation Projects in a Marginalised Community

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Abstract. This study explores the intersection of Higher Education for Sustainable Development (HEfSD), sustainable-smart innovation and the significance of local context in digital technology design, as captured in student-led projects within a marginalised community in Cape Town. As the global imperative to achieve the Sustainable Development Goals (SDGs) intensifies, integrating sustainable practices and innovative technologies at the local and community scale becomes paramount. This research investigates the potential of collaborative educational approaches in addressing complex sustainability challenges through the lens of a specific Cape Town community. The paper provides findings from the third iteration of a longitudinal Design-Based Research (DBR) study. Data includes interviews, participatory observations, and project artefacts. This research seeks to identify the enablers and barriers to validate an additional design principle for the implementation of sustainable-smart student projects. It examines the collaborative design thinking process, interdisciplinary approaches, and community engagement employed by students and educators to co-create sustainable-smart innovations that respond to both local challenges and global sustainability goals. By doing so, this study sheds light on the potential of HEfSD to nurture sustainable-smart innovation within unique socio-economic and cultural contexts. The research underscores the need for higher education institutions to embrace localised, student-centred initiatives that harness the power of innovation to drive positive change in marginalised communities, thus advancing both sustainability and social equity agendas.

Keywords: Information Systems Education · Sustainable-Smart Solutions · Higher Education for Sustainable Development · Local Knowledge · Design Thinking · Innovation-Based Learning

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1 Introduction

Currently, there is a pressing need to address global issues such as poverty, inequality, environmental degradation, and technological advancement as stipulated by the Sustainable Development Goals (SDGs). This requires collaborative partnerships that co-create sustainable solutions whilst maintaining a balance between ecological, economic, and socio-cultural concerns. Therefore within Information Systems (IS) education, social responsibility needs to become a core focus highlighting the ethics, human factors, and social consequences of emerging technologies. However, it is acknowledged that prevailing IS education often falls short in these domains [1, 2]. As argued by Heeks [3] a shift that incorporates the impact of digital technology within complex and intersectional systems of power is required to move from adverse to advantageous digital incorporation to seek digital justice in the global South. In response to this, a transdisciplinary student project focussing on SDG 11, which initiates sustainable-smart innovations within a marginalised community in Cape Town was implemented between two Higher Education Institutions (HEIs).

This paper proposes solutions to bridge the gap between global sustainability goals and local realities through student-centred sustainable-smart innovation projects within a marginalised community. We propose that students (as future designers) need to grasp the complexity of wicked problems that reside within the collective or societal sphere. The complexities of the collective voice and how a community depends on social relationships and relational structures to solve day-to-day and long-term problems. Thus the importance of a bottom-up, community-driven approach that corresponds with the specific contexts and needs of marginalised communities forms a central theme in this project. It is necessary to facilitate an understanding of the power dynamics of inequality within the design processes, resources, and institutions and in social structures [4]. Within this landscape, the role of higher education as a catalyst for sustainable change comes into focus, especially through the lenses of Higher Education for Sustainable Development (HEfSD), local context and sustainable-smart design.

The paper is organised as follows: a theoretical overview of the literature on the role of HEfSD, contextualising smart-city development solutions and the application of inclusive innovation. The next section provides some background to the student projects followed by the research methodology, results and a discussion of the findings to highlight the enablers and barriers within sustainable-smart learning to conclude the paper.

2 Higher Education for Sustainable Development

The urgent call for sustainable solutions that blend technological progress and cultural sensitivity requires action from HEIs to integrate the SDGs into their curricula [5]. As argued, sustainability should be a critical subject for prospective IS professionals and become a mainstream research topic, due to the integral nature of information in all development and innovation [6, 7]. However, there is limited literature on sustainability in the IS curricula [6–8]. In their analysis of existing degree programs, it was found that the integration of sustainability in the ICT curriculum is predominantly through separate green computing or environmental informatics courses, with limited evidence of traditional courses that make sustainability content a priority [6, 9].

A holistic view of what sustainability requires is needed to raise awareness among students, faculty, and the broader community to acquire the required competencies for sustainable development. A HEfSD framework developed by Franco et al. [10] proposes the co-creation of projects by applying human-centred future-focused theories and the co-design, monitoring and implementation of solutions among multiple stakeholders. This perspective recognises that HEIs need to transcend academia's traditional boundaries and foster cooperation and integration to adapt and build a shared commitment to societal betterment [11]. The effective resolution of societal issues and the facilitation of collaborative knowledge creation requires an understanding of the implications of transdisciplinary learning for present and future sustainability challenges [12]. Employing inter and transdisciplinary learning approaches equips students with the ability to navigate high uncertainty and encourages experimental and iterative approaches to challenges. In this paper, we present findings from a transdisciplinary project between IS students and students in Urban Planning (URP) who collaborated with multiple stakeholders within the community of Dunoon, Cape Town to develop digital social innovations linked to SDG 11.

3 Sustainable-Smart Development Solutions

The concept of "smart cities" has gained global prominence especially because of its ability to intertwine information and communication technology (ICT) with city systems and operations. This in a time when cities experience pressures from rapid urbanisation, environmental decline and economic downturns which negatively impact the quality of life of global citizens. Yin et al. [13] explain the progression of the smart city concept from its original digital city and intelligent city and provide the most comprehensive definition as the "integration of technological infrastructure that relies on advanced data processing with the goals of making city governance more efficient, citizens happier, businesses more prosperous and the environment more sustainable." This aligns with [14] who argues that it is a situation where technology is seamlessly integrated with physical, social, and business infrastructure to enhance optimisation, automation, efficiency and control. Current smart city endeavours frequently leverage big data and the Internet of Things (IoT) to enhance urban efficiency. However, the use of these technologies primarily for automation and control can potentially jeopardise citizens' privacy and freedom. On the flip side, these technologies also hold the potential to empower citizens, tap into collective intelligence, and generate value by adhering to open technology and social innovation principles [14, 15].

Odendaal [15] brings sustainability thinking into the smart city conversation when she foregrounds the human dimension of technology that interfaces with livelihoods in their particular spatial contexts arguing for the foregrounding of local dynamics. This draws attention to the interrelationship and interdependence of cities, their supportive technologies and the link with resource usage and waste production, thus framing the environment (sustainability) and technology (smart) within the urban context (city).

Within the context of this paper with its emphasis on marginalised communities and their positioning within sustainable-smart development solutions, opportunities for a deeper and more rounded understanding of technology appropriation are needed [15,

16]. Furthermore, sustainability should not be considered an outcome but a continuous process present in every stage of solution development and decision-making [16].

4 Inclusive Design: The Intersection of Local Context and Digital Innovation

The African Union's Agenda 2063 aspires towards a people-driven approach for inclusive growth and sustainable development with innovation being regarded as a key driver. However, a narrow focus on innovation for economic growth exacerbates existing inequalities particularly within marginalised communities [3, 17, 18]. In a review of innovation aimed at marginalised communities, multiple terms exist such as 'frugal innovation, pro-poor innovation, Bottom of the Pyramid (BOP) innovation, grassroots innovation and inclusive innovation' [18]. The authors argue that various innovation approaches target marginalised communities differently. Frugal innovation emphasises product quality and benefits for the marginalised. BOP categorises the marginalised by economic capacity, focusing on market success. Grassroots innovation centres on marginalised-led innovations and inclusive innovation necessitates active consultation, participation and engagement with the community at various stages of the innovation process, even if it's partial [18]. For our project, the focus is on inclusive digital innovation.

Inclusive community-based design is a continuous process of designing with and for communities to connect technological interventions with existing practices and local dynamics (social, cultural, political, economic, and spatial/physical) [19]. In the frugal innovation literature, an emphasis on inclusion, 'co-creation' and 'partnerships' is based on an assumption of complementarity between the formal and informal economies, in which linkages with multinational corporations, NGOs, governments and other formal sector actors can be used to overcome the limitations of informal economic arrangements at the bottom of the pyramid [20]. Genuinely complementary engagement with the bottom of the pyramid requires a greater awareness of informal economies as systems in their own right, rather than as raw materials for the construction of new low-cost business ecosystems for corporate actors [14]. The interaction between the design process and the community's situation creates a complex and dynamic setting where design researchers and communities co-create innovative technological solutions. The driving force is that it emerges from and simultaneously can be integrated into the local context to further empower and build the community [19].

Furthermore as argued by Mungai et al. [18] the focus in literature is predominantly on products, less on processes and even less on people. Therefore a better understanding of innovation within marginalised settings requires the documentation and discussion of the processes of innovation and an exploration of agency. The competencies required to infuse agency in inclusive innovation projects for learners to understand the underlying values and motivational drivers of sustainability include future thinking, systems thinking, normative ethics, intra-personal and strategic skills [21, 22].

5 Background to the Student Project

This paper discusses findings from the third iteration (2023) of a student project that commenced in 2021 between post-graduate students in IS and URP. The design of the learning environment for the project is rooted within the broader design science paradigm by applying a Design-Based Research (DBR) approach. Within this approach, the researchers gain an in-depth understanding of a problem before any prototype solution is designed and tested [23]. The findings offer both theoretical insights and practical solutions, together with stakeholders within authentic settings through an iterative process of testing, refining and aligning theory, design and practice [24]. The design principles developed within the first two iterations included:

Design Principle 1: Context-Sensitive Learning: 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;
Design Principle 2: Co-construct Knowledge: The importance of considering all the role players (human and nonhuman) and their contribution to knowledge creation and developing relevant solutions;
Design Principle 3: Socio-technical and socio-cultural entanglement: 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; and
Design Principle 4: Relationality and Agency: Positioning society and communities at the centre of both education and the current and future role of technology. It is strongly human-centred and as such recognises the power dynamics that exist.

During the second iteration (2022), it became clear that digital social innovations need to be grounded in sustainable principles, to prepare our students for the complex challenges of our rapidly changing world. This led to the development of another design principle namely the inclusion of sustainable-smart parameters in the projects in the third iteration (2023). Drawing on a review of the literature the inclusion of the fifth design principle within the learning environment includes the following parameters as illustrated in Fig. 1.

The study area for the assignment in 2023 was the informal settlement of Dunoon in the Blaauwberg district of the City of Cape Town. Eight themes developed from the City of Cape Town's strategic development policies were randomly assigned to the teams including challenges related to the informal economy, lack of public services and facilities, informal housing, unemployment, lack of sanitation, lack of recreation opportunities, challenges to the natural environment and food security.

6 Research Methodology

In this paper, we discuss the testing and refinement of a design principle that was included in a student project as discussed in the previous section. The research applies a four-phase method:

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.

A DBR study is longitudinal and consists of a collection of sub-studies that are reported separately. The study is currently in Phase 3 and two iterations have been completed in 2021 and 2022 with findings from the third iteration presented in this paper. A qualitative analysis of the data consisting of student blogs, project artefacts and semi-structured interviews. The components illustrated in Fig. 1 were applied to the thematic analysis of findings. Participants included 35 students from the Honours group in Information Systems (IS) from one university in Cape Town and 23 students from the Advanced Diploma in Urban and Regional Planning (URP) from another university with community representatives. The group project was part of the overall learning outcomes and assessed in both modules. Permission was obtained from students to have their findings and reflections included in the data as well as ethical approval for the overall study from both universities.

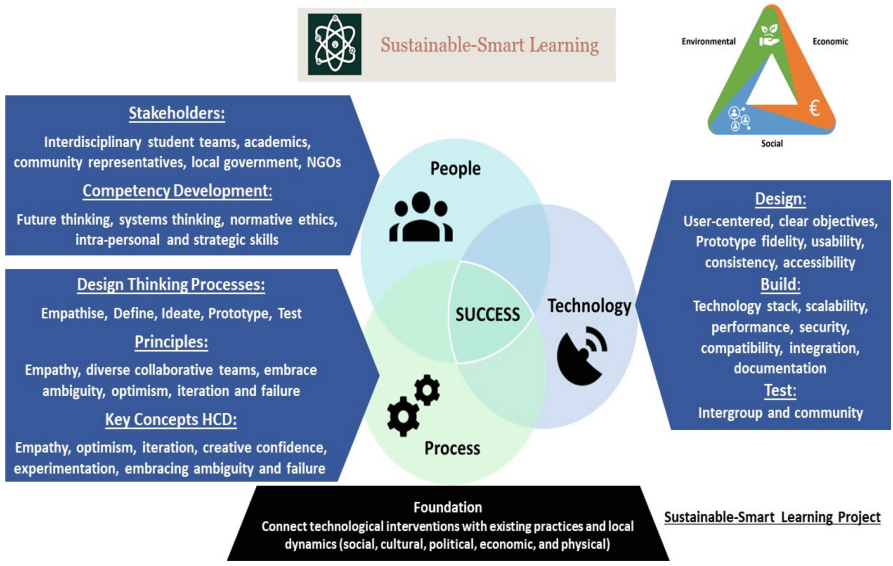


Fig. 1. Sustainable-Smart Learning Parameters

7 Discussion and Findings

The analysis of findings applied the components as identified in Fig. 1 to review the outcomes and identify the enablers and barriers to implementing sustainable-smart learning.

7.1 People Analysis

The analysis of findings used the competencies identified by [21] to test the findings from the interaction among the different stakeholders.

Interpersonal and intrapersonal: This was tested by considering aspects such as self-awareness, meaning-making, self-reflection, communication skills, empathy, teamwork, and collaboration. The development of collaboration, team work and communication was emphasised strongly in most of the group reflections. For example:

> *Collaboration with diverse teams, brings about innovative solutions. When we focus on what we know and our expertise solutions can be limited to only our knowledge, but working with a team from another discipline expands the potential for a solution (R20).*

Future Thinking: The development of competencies such as visioning, developing scenarios, backcasting, recognising heritage, and intergenerational equity was tested. The data highlight the competency of scenario planning as able to enhance decision-making and preparedness for potential challenges and a diverse future. A forward-thinking mindset is essential for responding to uncertainties and promoting sustainable solutions. Examples from student reflections include:

> *Scenario planning helped us envision different future scenarios. As a result, we were able to be proactive and implement various methods to mitigate the threats i.e. increase the longevity of the product as well as make it resilient, adaptable, and prepared for the future (G4).*

> *I enjoyed the Future Planning it was interesting to see how you would break down possible future events in the Information System world and then create scenarios of those outcomes (R5).*

Systems Thinking: In this competency area components such as working with complex problems, promoting resilience, understanding tipping points and feedback loops were reviewed. Through our analysis of student reflections, it became clear that initial struggles in group assignments stemmed from a tendency to force solutions onto complex problems rather than facilitating participatory problem-solving. This highlights the importance of resilience within systems thinking by empowering individuals to collaboratively devise solutions. The findings also underscore the interconnected nature of problems, and how understanding tipping points and feedback loops can address nested challenges effectively, thereby fostering a more sustainable and resilient future. For example, as quoted by one group:

This is what we initially struggled with at the start of the group assignment. We wanted to fit the solution we had to the problem rather than letting the people experiencing the problem come up with the solution themselves (G3).

Reflections from students also highlighted this for example:

One solution does not solve all the problems. This was a lesson learned as we did our literature review. The second time we did it I did some research and with the group assignment I quickly learned these problems are nested and solving one problem can assist in another problem area and how we incorporate it into one another can help alleviate more problems to strive for a better future (R4).

Disciplinary and interdisciplinary: The findings suggest that working as part of an interdisciplinary team can foster collaboration among students from different contexts, leading to a richer exchange of perspectives and sharing of expertise. Initial apprehension about collaborative interdisciplinary work emerged in student reflections, but groups found ways to navigate the diverse and complex relationships and make diversity a strength. For example:

One aspect of the project that I was particularly apprehensive about was working with another group of students from a different university. However, I was pleasantly surprised by how well both groups worked together (R11).

Normative and Cultural: The components that were focused on included ethical responsibility, development of world views and perspectives, awareness of values, understanding of justice, awareness of local context and global trends. This essential, but highly complex competency, manifested in most student reflections as we deliberately designed the project with normativity and cultural sensitivity in mind. The findings underscore the ethical responsibility inherent in technological innovation by emphasising the need for cultural sensitivity. Students highlighted feeling a sense of responsibility for ensuring a meaningful community impact. By engaging with a specific community, a deep understanding and awareness of the local context was facilitated. For example from a group reflection:

By leveraging technological advancements and interdisciplinary collaboration, the prototypes developed have the potential to positively impact the lives of those in need. The project demonstrates the transformative power of technology and the value of interdisciplinary collaboration in tackling societal issues (G3).

Individual reflections by students also highlighted this for example:

We learned that we need to be sensitive to different cultures and adjust how we engage with different people. This experience helped us understand how complicated communication can be in a multicultural society (R6).

This project instilled a sense of responsibility and empathy within us. Witnessing the living conditions and struggles faced by the community of Dunoon highlighted the urgency and significance of addressing the issues at hand (R15).

Strategic: The findings suggest that adopting an iterative approach to system development, focused on user involvement can enhance the potential of digital solutions. By continuously considering the user perspectives and making use of feedback and reflection cycles, an environment is created that places less focus on the end product and more on the process of refinement and responsiveness. For example:

> *By incorporating feedback and conducting design validation, we ensured that the final prototypes effectively addressed the water pollution issue in Dunoon. This process taught us the importance of user involvement, iterative refinement, and validation in creating impactful designs (R30).*

7.2 Process Analysis

In the analysis of the process, a review of student and community reflections and feedback took place to identify the enablers and barriers within the roll-out of the projects.

The student groups applied design thinking following a sequence of phases in the roll-out of their projects. For a detailed perspective from one of the teams please see their e-portfolio at: **Clean Streams Part 1.**

The phases consisted of the following:

Pre-Production Phase: The project commenced with the formation of groups, the students could select two team members that they would prefer to work with and thereafter students from the two universities were randomly placed into eight groups of six to seven members each. Groups had to complete a code of conduct and select a group name and group roles. Thereafter a problem area was assigned to each group and they had to conduct a literature review to further define the problem area. Groups needed to develop a deep understanding of the problem as mentioned by a student:

> *We recognized the significance of clearly defining the problem and conducting a thorough analysis before diving into solution development. By taking the time to understand the root causes and context of the problem, we were able to design appropriate and effective interview questions (R13).*

Phase 1: Empathise and Define: During this stage, teams collaborated to plan and draft interview questions to conduct research in the community. Interviews took place during a site visit in Dunoon where each team interviewed approximately 10 residents to gain their perspectives on the problem area. The interviews were recorded and transcribed and resulted in the creation of Personas and digital stories. Feedback from students highlights the importance of engagement with the community for example:

> *We reached out to the residents of Dunoon to understand their needs, aspirations, and concerns. We analysed the data to identify key patterns, trends, and priority areas. We brainstormed potential solutions, considering factors such as sustainability, affordability, and scalability (G2).*

> *I learned that the information available and the first-hand information gathered during the site visit may offer differing perspectives on the issue. It is possible*

that the authors of online resources may not have fully immersed themselves in the complexities of the problem (R10).

Phase 2: Ideate and Prototype: The ideation took place during the "maker week" where teams had to follow the principles of brainstorming and each member had to select 20 or more potential ideas. Several tools to stimulate creativity were applied during the brainstorming sessions. Teams followed a process of refining the ideas, categorising them and applying a decision matrix to select the top 10 ideas that could potentially be prototyped. Further brainstorming and refinement of these ideas resulted in the top four ideas to prototype. The experience is captured in the following reflections by a student:

When we began designing our prototypes, the lecture said no idea was a bad idea. I thought to myself that can't be true. However, when I took the advice and came up with my own 20 ideas those wacky ideas came in handy as we were able to build from it (R18).

Phase 3: Test: Prototypes were tested by other groups, the facilitators and representatives from the community. Students had to complete a questionnaire consisting of 15 questions during the testing of prototypes. The results were collated and the top two prototypes were identified. The findings also provided insight into the improvement of prototypes. For example, as reflected:

We embraced an iterative design process, continuously striving for improvement. By incorporating feedback loops, prototyping, and user testing, we identified areas for enhancement and refined our digital solutions iteratively (G 6).

The project solutions were also presented to representatives of the City of Cape Town during and exhibition and one stakeholder provided the following feedback:

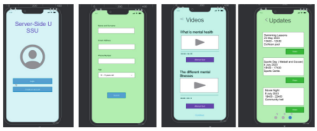
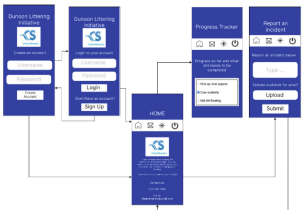
The problems that the groups investigated are all extremely complex and what they achieved was phenomenal. I am very interested in the data-free solutions and the fact that they used the perspectives of real people making the community the champion. The government can only go that far it helps to have the community voice presented in the solutions. Context matters and you cannot directly translate problems from one context to another, using the storyline from the community is very powerful.

Phase 4: Solution Design: This phase consisted of a detailed design of the final prototypes by each group. The design included the documentation of the prototype user design specifications, user stories, functional and non-functional requirements and technical design specifications. The groups were also required to conduct scenario planning to test their solutions for potential future scenarios. The solution design is discussed in the next section.

7.3 Technology Components

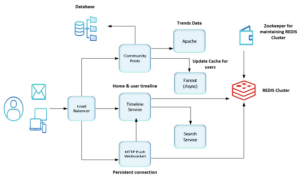
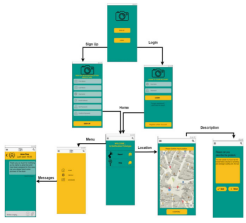
The interdisciplinary teams developed four prototypes as highlighted in the section above. The four prototypes were tested by other groups and from the findings, two

Table 1. Final solutions developed per team

Team Name and Theme	Final Prototypes
Urban Visionaries worked with informal housing challenges 	The Dunoon Community Grievance Forum (DCGF) Application connects the residents to the community decision-makers to lodge their complaints, report illegal activities and track progress. EduDunoon is a digital platform that provides access to resources, such as step-by-step guides for constructing and maintaining low-cost, eco-friendly housing solutions using local materials and resources as well as educational resources such as videos and tutorials on building solutions and flood hazards.
Server-Side Us concentrated on the lack of mental health facilities and services 	A mood tracker application that enables the user to track their emotions throughout the day to identify patterns and triggers that affect their mental health to better manage their emotions and overall mental health. A data-free mental health app to provide accessible mental health resources and support in Dunoon.
StrategicUrban focused on food security challenges 	The two final prototypes include a crop-growing application and a Community Food Hub application. These prototypes aim to reduce food waste, increase access to fresh produce, promote community involvement in urban agriculture, and provide emergency food assistance. The focus is on developing technology-driven solutions that can be commercialised, ensuring their long-term viability and scalability. The applications use a data-free approach.
CleanStreams reviewed the challenges of water pollution and sanitation 	This team designed a mobile application and data-free website that aims to empower the community by raising awareness about water pollution and promoting sustainable practices for improving water quality in the Diep River in Dunoon. By leveraging technology, the idea is to bridge the information gap and encourage community engagement.

(*continued*)

Table 1. (*continued*)

Urban Economic Evolution: addressed challenges faced by the informal economy (spaza shops and vendors) 	The team designed a community hub application to provide vendors with the ability to create a profile on the hub to showcase products and services including networking functionalities and educational material. The other application is a food delivery mobile application aimed at residents that connects local vendors to consumers. The application facilitates transactions between the vendors and users, with a dedicated cyclist acting as a bridge, collecting goods from vendors and delivering them directly to consumers.
Hygeia focussed on sanitation challenges including access to clean water and sewage 	The team designed an application that provides clean water to residents that connects a local vendor to residents and provides payment and delivery functionalities. The second application provides residents with the functionality to report sewage spills to the local authorities. It also provides educational material on water and sewage challenges and how to address them.
Rooted in Dunoon focussed on issues around unemployment 	The team designed the FundamentaLearn application which aims to upskill individuals with scarce skills and interests that could make them more employable. The team also designed the Bookeepa application which provides entrepreneurs with the professional and administrative services that they need for their businesses. It is a user-friendly platform that streamlines critical business processes. One of the core features of Bookeepa is the provision of default documents, such as statements, invoices, and pricing sheets, all conveniently accessible within the app.
Play-Crafters reviewed challenges linked to the lack of recreational opportunities. 	The team designed a mobile application that allows the residents of Dunoon to be able to sign up for recreational activities in the area, start a new team or group and obtain feedback on upcoming events. The application also enables contact with the local municipality on issues related to the maintenance of recreational facilities. The second output is a website that allows users to make donations as well as register for recreational fundraising events. It is a site that also explains the importance of recreational activities and their benefits. The site is free to access and is very user-friendly.

final prototypes to further develop were selected by each group. The development of the final solutions followed the process of documenting the design specifications, user stories, functional and non-functional requirements, design architecture and technical specifications. Documented specifications are required to enable the potential build and implementation of solutions once further funding and support are obtained. The final prototypes per group are described in Table 1.

The review of solutions showed that most groups had a very good grasp of user-centred design as a result of the detailed exploration of the problem from the community's perspective. The creation of personas and digital stories and the translation thereof into detailed user stories and requirements assisted with this. Furthermore, the rigorous testing and refinement of the prototypes by other teams and some stakeholders from the community was also beneficial. In the design specifications, the focus was on intuitive and user-friendly interfaces that allow users to, for example, browse menus, place orders, and track deliveries with minimal effort. There was also a good grasp of aspects such as cost reductions to eliminate data charges for users, the inclusion of different languages, spatial accessibility and one team included features for users with disabilities.

8 Recommendations

This section highlights the enablers and barriers that need to be considered when developing and implementing SDG-focused student projects in the IS curriculum.

Project-level enablers that were highlighted by the data are the advantage of diverse perspectives through interdisciplinary collaboration. The value of community engagement in addressing real-world challenges is also strongly emphasised. Complex social issues and context-specific environmental and economic challenges cannot be well understood or resolved by "expert" research. Embedding the SDGs in the curricula can be strengthened through iterative development to ensure responsiveness to stakeholder feedback, and prioritising ethical responsibility and cultural diversity in project design. It is considered that these enablers can lead to student and community empowerment and agency which is needed to ensure continuity from problem identification to solution implementation.

At an institutional level, enablers include support within the HEI environment towards resources and funding mechanisms to assist complex student projects. Furthermore, engagement with external partners such as NGOs and local municipalities is needed to share both their local knowledge and provide entry into communities.

The overarching enabler in this project is the opportunity for both students and community members to develop a deeper understanding of local socio-economical-ecological challenges and collaboratively develop potential technological solutions.

The most prominent project-level barrier is time constraints as a project of this nature is time-consuming for both lecturers and student groups and it needs to fit into the deadlines set by universities. A further barrier is the levels of complexity that students need to engage with to contextualise the SDGs within a local context. Another barrier was that the solutions developed were restricted to mobile applications and digital platforms as this was more familiar to the students. More work is needed in future iterations to encourage, for example, the implementation of IoT sensors linked to real-time data

collection, fintech solutions for the informal economy, and affordable renewable energy solutions.

Institutional level barriers are the challenging socio-economic context for both students and community members which has a direct impact on their access to technology, socio-cultural barriers between different stakeholder groups with language and community expectations being a major hindrance to building trust.

The main overarching barriers when working with a community as part of an interdisciplinary student project are to define the measurement of success and failure, what to do with the failures, and how to protect the community and their livelihoods against project failures, thus the ethical considerations and the strong sense of responsibility. The expected local impact becomes even more challenging when donor agencies, especially international donors, are part of the stakeholder team. In future iterations of this project, more emphasis needs to be placed on finding community-sensitive ways of testing and implementation. This phase needs wider input from community members, industry stakeholders, local government representatives and NGOs and potentially international collaboration for the commercialisation of solutions.

9 Conclusions and Future Research

This paper underscores the critical intersection between local realities and global sustainable development goals and how a student project can be used to bridge the gap. The student project's main objective was to collaboratively engage complex sustainability challenges within a specific marginlaised community and to develop through an iterative process, innovative and relevant technology solutions.

We reflected on the people, process and technology requirements to implement sustainable-smart learning and highlighted the enablers and barriers from a project and institutional level. Enablers such as interdisciplinary collaboration, community engagement, iterative development, and ethical responsibility are highlighted to enable a holistic understanding and innovative solutions to complex social issues. However, challenges such as time constraints, technological limitations, and socio-economic barriers underscore the need for strategic interventions and adaptive approaches in project design and execution. Addressing these barriers requires a concerted effort to navigate complexities, foster trust among stakeholders, and uphold ethical standards, particularly in the face of diverse socio-cultural contexts.

We acknowledge that the study is limited to findings from the geographic region and the scope of projects. A further limitation is the lack of rigorous testing and implementation of solutions beyond the development of prototypes. Further limitations such as the lack of resources including time, funding and access to sophisticated technology had an impact on the design of solutions.

Moving forward, future iterations must prioritise community-sensitive testing and implementation processes, involving a wide variety of stakeholders ranging from community members to international collaborators. HEfSD initiatives as presented in this paper, can advance both social equity and environmental sustainability agendas and as such contribute to the current body of literature. Apart from an academic contribution, this research also provides lessons for interdisciplinary practices, especially in the

context of the global south with its resource scarcity and social inequalities. Ensuring that users, especially the most marginalised, are part of the technology development phases ensures a fit for purpose and sustainable end product. We are all bound by the planetary care principle to make every contribution to achieving the SDGs which necessitates our students, as future professionals, to be able to localise challenges and find contextually-sensitive, innovative solutions.

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