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Urban Living Lab as an Education Strategy for Sustainable Development

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Abstract

This study analyses the Delta Project, an Urban Living Lab (ULL) implemented at the Faculty of Architecture and Urbanism (FAU) of the University of Guayaquil (UG), as an innovative educational strategy for sustainable development. It highlights the challenges in architecture education, focusing on the need to adapt to the demands of sustainability and technological advances. ULLs, in response to these challenges, are presented as dynamic platforms that combine research, innovation and policy to promote sustainability in urban and educational contexts. The methodology employs a case study approach, detailing how the Delta Project is integrated as a learning environment at FAU and its relationship to sustainability goals and education for sustainable development (ESD). The E-ULL-HEIs tool was used to assess seven key indicators: objectives and scope, diversity and stakeholder participation, interdisciplinarity, curricular integration, learning and research impact, community impact, and resources and sustainability. Data were collected through semi-structured interviews, documentary analysis and participatory observation. The results indicate that FAU has successfully integrated the Delta Project into its educational programmes, highlighting its impact on diversity and stakeholder participation, interdisciplinarity, curricular integration, and learning and research. The findings underline the effectiveness of the Delta Project in promoting ESD and its alignment with the Sustainable Development Goals (SDGs). However, challenges were identified in terms of cross-sectoral collaboration and student participation, providing valuable lessons on the importance of strategic planning and adaptability. The study highlights the potential of the Delta Project model to be adapted and replicated in different cultural and academic contexts, suggesting the

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need for ongoing evaluations to improve the effectiveness of similar projects and promote ESD.

Keywords: architecture education challenges; innovative teaching methods; Project Delta Guayaquil; Guayaquil urban projects; sustainable urban development; educational strategies.

Urban living Lab como estrategia educativa para el desarrollo sostenible

Resumen

Este estudio analiza el Proyecto Delta, un Laboratorio de Vida Urbana (ULL) implementado en la Facultad de Arquitectura y Urbanismo (FAU) de la Universidad de Guayaquil (UG), como una estrategia educativa innovadora para el desarrollo sostenible. Pone de manifiesto los retos de la enseñanza de la arquitectura, centrándose en la necesidad de adaptarse a las exigencias de la sostenibilidad y los avances tecnológicos. Las ULL, en respuesta a estos retos, se presentan como plataformas dinámicas que combinan investigación, innovación y política para promover la sostenibilidad en contextos urbanos y educativos. La metodología emplea un enfoque de estudio de caso, detallando cómo se integra el Proyecto Delta como entorno de aprendizaje en la FAU y su relación con los objetivos de sostenibilidad y la educación para el desarrollo sostenible (EDS). Se utilizó la herramienta E-ULL-HEIs para evaluar siete indicadores clave: objetivos y alcance, diversidad y participación de las partes interesadas, interdisciplinariedad, integración curricular, impacto del aprendizaje y la investigación, impacto en la comunidad, y recursos y sostenibilidad. Los datos se recogieron mediante entrevistas semiestructuradas, análisis documental y observación participativa. Los resultados indican que la FAU ha integrado con éxito el Proyecto Delta en sus programas educativos, destacando su impacto en la diversidad y la participación de los interesados, la interdisciplinariedad, la integración curricular y el aprendizaje y la investigación. Los resultados subrayan la eficacia del Proyecto Delta en la promoción de la EDS y su alineación con los Objetivos de Desarrollo Sostenible (ODS). Sin embargo, se identificaron retos en términos de colaboración intersectorial y participación de los estudiantes, proporcionando valiosas lecciones sobre la importancia de la planificación estratégica y la adaptabilidad. El estudio destaca el potencial del modelo del Proyecto Delta para ser adaptado y replicado en diferentes contextos culturales y académicos, sugiriendo la necesidad de evaluaciones continuas para mejorar la eficacia de proyectos similares y promover la EDS.

Palabras clave: desafíos de la enseñanza de la arquitectura; métodos innovadores de enseñanza; Proyecto Delta Guayaquil; proyectos urbanos de Guayaquil; desarrollo urbano sostenible; estrategias educativas.

Introduction

The teaching and learning process in faculties of architecture faces the challenge of adapting to the growing demand for sustainability and technological advances, and this adaptation is crucial for its relevance and effectiveness (EDUCATE, 2012; Sachs et al., 2022). In this context, higher education requires an interrelation between research and teaching (García Rivera, 2021), research, training and the transmission of knowledge to society constitute the pillars of contemporary education (Chávez, 2015).

Traditionally, architectural education has focused on project workshops that seek to be more inclusive and collaborative. However, it is noted that significant changes in this approach have not yet been achieved (Nicolau-Corbacho et al., 2019). Masseck points out that architects' learning should be linked to real projects and life experiences through visits and direct perception of materials, space and light (Masseck, 2015).

In response to these challenges, Urban Living Labs (ULLs) emerge as an innovative solution in the field of teaching and learning, responding to contemporary sustainability challenges (Piziak et al., 2023). These labs represent an urban intervention with clear sustainability objectives, standing at the confluence of research, innovation and policy (Bulkeley et al., 2016). Globally, several ULLs have demonstrated their effectiveness in integrating sustainability into urban and educational contexts.

These labs have been implemented globally in diverse geographies and institutional contexts, not only focusing on the integration of sustainability in urban and educational contexts, but also varying in intensity and methodology depending on the approach and stakeholder involvement. For example, the Water Resources Plan of the University of South Santa Catarina in Brazil (Amorim et al., 2020), and LOW3 (Masseck, 2017) in Spain, have successfully applied strategies to promote urban sustainability through active multi-stakeholder collaboration. Projects such as the Malmö Innovation Platform (McCormick & Kiss, 2015) and the Living Lab at the University of Manchester (Evans et al., 2015) are deeply rooted in their respective communities, generating immediate and tangible impacts due to their commitment to co-creation and participatory design. In contrast, initiatives such as the SubUrbanLab place greater emphasis on influencing urban development policy and practice, resulting in broader and less direct impacts (Federley et al., 2014).

At the core of these labs, such as Delft University of Technology (Mulder & Stappers, 2016) and the Malmö Innovation Platform (McCormick & Kiss, 2015), co-creation and participatory design are extensively adopted. These strategies not only optimise learning outcomes but also actively promote community participation by integrating users throughout the innovative process (Steen & Bueren, 2017). This hands-on approach allows participants to deeply immerse themselves in the innovation process through discovery learning, interaction and experimentation, which fosters a robust understanding of sustainable urban development (McCormick & Kiss, 2015).

In contrast to this, the University of Manchester's Living Lab prioritises experiential learning, applying academic theories to real sustainability problems within the university campus (Evans et al., 2015). This method not only provides valuable hands-on experience but also serves to bridge the gap between theoretical knowledge and its practical applications, thus elevating the relevance of academic studies in the real-world context.

The impacts derived from these learning strategies are both profound and diverse. The University of Southern Santa Catarina (Amorim et al., 2020), for example, has integrated

sustainability into its curriculum in a way that has significantly improved environmental awareness and local resilience. In addition, the building engineering teachings at these ULLs stand out for enhancing employability and professional competencies, equipping students with the tools necessary to face the complexities of modern engineering challenges (O'Brien et al., 2021).

Similarly, Lund University's Urban Arena stands out for its holistic approach that merges research, education and innovation, focusing on improving urban environments and demonstrating the role of academic institutions as catalysts for sustainable urban development. This integrative approach involves diverse disciplines and sectors, enriching the educational landscape and fostering community engagement (McCormick & Kiss, 2015).

Furthermore, the Federal University of Lavras, recognised as a living laboratory, has initiated projects ranging from efficient water and energy management to sustainable transport, significantly increasing campus sustainability and serving as an educational and practical model for broader community engagement (Pantaleão & Cortese, 2018). The case of Suurpelto in Finland further highlights the crucial role of students as agents of innovation within ULL, underlining the importance of student involvement in sustainability projects, which not only contributes to their educational trajectory but also impacts the sustainable development of ULL (Juujärvi & Pesso, 2013).

Overall, the evolution of ULLs from stand-alone projects to integrated platforms reflects a dynamic and contextual approach, where different objectives and activities are combined in real-life scenarios (Sengers et al., 2019; von Wirth et al., 2020). This approach enables a significant contribution to global sustainability while fostering innovation in solving societal problems. Being aligned with the Sustainable Development Goals (SDGs), ULL stands out in higher education by integrating geographic understanding and population needs with active participatory action, offering a practical, applied and multidisciplinary learning environment that is in line with current demands for academic training and professional development (Defila & Di Giulio, 2019; Morales et al., 2023).

In this context, the Delta Project in Guayaquil stands out as a ULL that promotes innovation and sustainability in teaching and learning in the Faculty of Architecture and Urbanism (FAU). Through a collaborative and multidisciplinary approach, bringing together actors from the quintuple helix, model representing different sectors of society: academia, industry, government, civil society and environment, working together to foster knowledge creation, innovation and sustainable economic and social development (E. Carayannis & Campbell, 2013) this project integrates professional practice and academia, addressing the challenges of urban sustainability and community development, which is characteristic of urban sociology, which studies social problems in urban contexts (Gottdiener et al., 2019).

The main aim of this article is to investigate how the Delta Project, as a ULL at UG's FAU, contributes to the practice and theory of sustainable architecture and urbanism, and how it fosters innovation and sustainability in higher education.

The specific objectives of the article are as follows:

To analyse sustainable urban renewal projects as learning environments in the field of architecture and urbanism, with a focus on the experience of the Delta Project in Guayaquil, evaluating its performance based on the seven indicators

of the evaluation tool of the Urban Living Laboratory in HEIs towards Education for Sustainable Development (E-ULL-HEIs).

Evaluate the role of the UG's FAU in the support and design of regeneration within the Delta Project.

Identify and discuss the specific challenges that arise when incorporating the quintuple helix in collaboration to promote sustainability and innovation in sustainable urban renewal projects, with a focus on the context of Guayaquil.

The research questions that guided this work are the following:

How has the Guayaquil Delta Project been integrated as a learning environment at FAU?

To what extent have the objectives of sustainability and education for sustainable development (ESD) been clearly defined in the context of the Delta Project?

How is the performance of the Delta Project assessed in relation to the seven indicators of the E-ULL-HEIs evaluation tool in terms of clarity of objectives, diversity and participation of actors, interdisciplinarity, curricular integration, impact on learning and research, impact on the community, and resources and sustainability?

What is the role of the UG's FAU in the design and support of the regenerations within the Delta Project?

How is the participation of FAU faculty, researchers and students in the Delta Project encouraged as part of a real-world project-based learning approach?

To what extent does this participation align with the indicators of the E-ULL-HEIs evaluation tool, especially in terms of diversity and participation of actors, interdisciplinarity and curricular integration?

What are the specific challenges in incorporating the quintuple helix (academia, industry, government, civil society and environment) in collaboration to promote sustainability and innovation in the Guayaquil Delta Project?

Location of study case and general information

The FAU: context

The FAU is located within the university campus in the city of Guayaquil, Ecuador. It is located in the north of the city, between the Malecón del Salado, Delta Avenue and Kennedy Avenue (Figure 1). The UG, as the largest higher education institution in the country and the oldest in Guayaquil, is home to approximately sixty thousand students, three thousand teachers and two thousand staff in its seventeen faculties and fifty-six academic programmes. (Passailaigue, 2019; Universidad de Guayaquil, 2019).

FAU offers two core undergraduate programmes: Architecture and Interior Design. These programmes attract a remarkable number of students, with approximately fifteen hundred enrolments per year. Of these, the Architecture degree is the most in demand, attracting the interest of around twelve hundred students each year. In a significant expansion of its academic catalogue, the FAU has increased its postgraduate offerings, now offering five master's degree programmes.

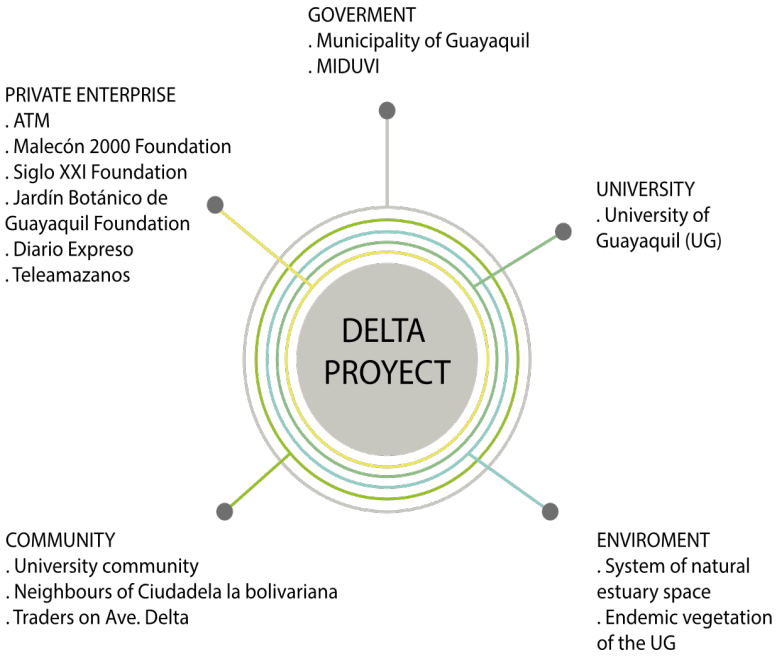
Figure 1. **Location of the "Ciudadela Universitaria", University of Guayaquil, between Delta Avenue and Kennedy Avenue,** adapted (Hugo et al., 2018).

The Architecture degree, taught over ten semesters, is based on four essential areas of knowledge: social, technical, design and expression. The area of design constitutes the central axis of the Architecture degree, with the subject of "Projects" functioning as an integrating nucleus. These areas are complemented by essential undergraduate components such as pre-professional internships, community outreach and degree work. This multidimensional approach is crucial in FAU's academic framework. However, challenges have been identified regarding the integration of sustainability concepts and synergy between different subjects. Traditionally, there has been limited correlation between the theory taught and its practical application.

Delta Project: general information

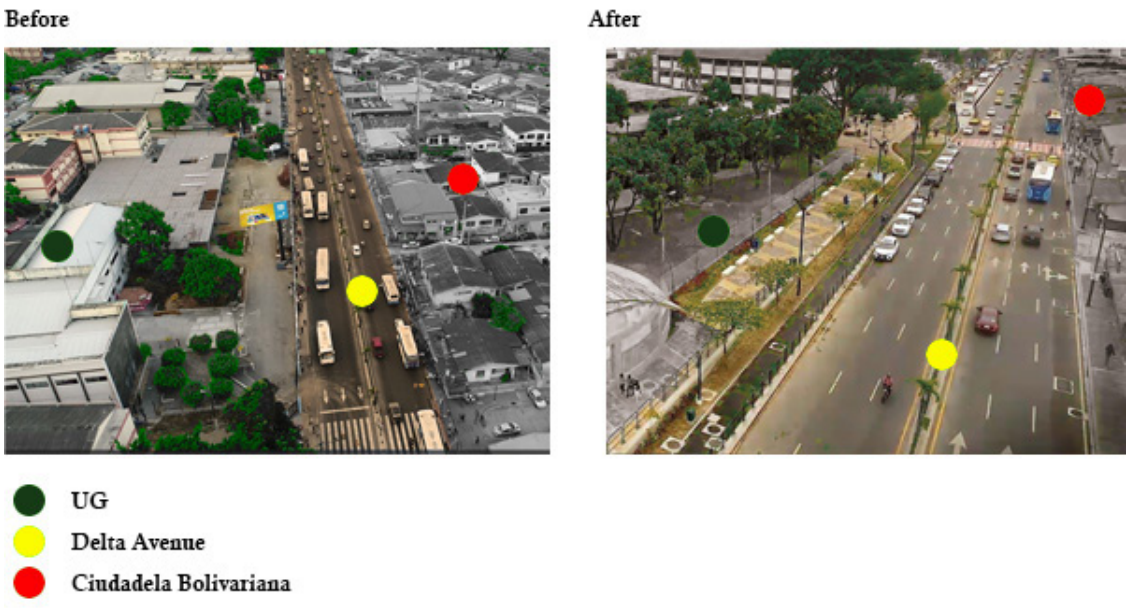
The "Delta Project" represents an innovative initiative within the ULL, focused on improving urban infrastructure and the built environment in Guayaquil. This initiative, led by the UG, focuses on optimising key aspects such as accessibility, green areas and urban mobility. Noted for its collaborative approach, the project integrates the perspectives of academia, government, private enterprise, society and the environment, following the quintuple helix model. Figure 2 illustrates a quintuple helix schematic of the Delta project.

Figure 2: **Quintuple Helix Scheme in the Delta Project,** based on Carayannis (E. G. Carayannis & Campbell, 2021)



The Delta Project is structured around three main interventions: the revitalisation of Avenida Delta, Avenida Kennedy and the interior of the Ciudadela Universitaria. This analysis focuses on the first phase, corresponding to Avenida Delta. This road, with a length of 548 meters, is not only the main access to the university campus, but also a crucial traffic node, handling a daily flow of approximately three thousand vehicles and two thousand pedestrians at peak hours (TORRES, 2017). Figure 3 shows a picture of the situation before and after the intervention on Delta Avenue.

Figure 3: **Delta Project before and after the intervention**



Materials and Methods

This study was conducted using a case study approach, which allowed for an in-depth and contextualised exploration of the Delta Project as a ULL in the city of Guayaquil. The case study was considered appropriate to understand in detail how the Delta Project is integrated as a learning environment in the UG's FAU and how it relates to sustainability goals and ESD. The E-ULL-HEIs tool (Morales et al., 2024) was used to assess the performance of ULL with respect to ESD in HEIs. The tool consists of the assessment of seven indicators, which are presented below:

Clarity of Objectives (COI): assesses how the objectives of the Delta Project align with ESD principles.

Stakeholder Diversity and Participation (SDPI): analyses the degree and effectiveness of stakeholder participation in the project.

Interdisciplinarity (IDI): measures the integration of different disciplines in the Delta Project.

Curricular Integration (CIIU): assesses how the Delta Project is integrated into the existing curriculum.

Impact on Learning and Research (LRII): examines the impact of the project on practical learning and research.

Impact on the Community (COII): assesses the effect of the project on the local community.

Resources and Sustainability (RSI): analyses the sustainability of the resources used and the results of the project.

The indicator evaluation criteria are assessed on a three-point Likert scale, with the options 0: Low, 1: Moderate and 2: High. The formula for determining the value of the indicator is the average of the evaluation of the criteria, defined as:

INDICATOR = (Σ (Ci * PCi)) /N; where,

Σ represents the sum of the criteria assessed in the projects.

Ci represents the score assigned to criterion i on a scale from 0 to 2.

PCi represents the importance or relevance of the criterion in the set of criteria. All criteria are considered to be of equal importance.

N is the total number of criteria assessed.

Data collection

Data collection was carried out through the following sources and methods:

Semi-structured interviews: Interviews were conducted with key participants in the Delta Project, including teachers, researchers, students and other actors involved in the quintuple helix. These interviews focused on the integration of the Delta Project as a learning environment, the definition of sustainability and ESD objectives, and the evaluation of its performance in relation to the indicators of the E-ULL-HEIs tool.

The purpose sampling method was used to identify the sample of participants for the semi-structured interviews (Palinkas et al., 2015). Specific criteria were defined, based on the objectives of the project, key participants were identified considering relevance and expertise, due to their direct and specific knowledge of the Delta Project (Wan, 2019). Representativeness, being that the diversity of participants with various roles within the project allows for a full range of perspectives and experiences to be captured, facilitating a better understanding of how the project operates at different levels and functions (Chatters et al., 2024). Feedback from the interviewed participants was used to identify potential participants and an iterative review was conducted as interviews were reviewed based on the emerging information. The interview methodology was designed to explore specific aspects of the project, according to the E-ULL-HEIs tool dimensions, ensuring that the data collected is directly relevant to the issues under investigation, in line with the objectives of the study (Melvin et al., 2020).

Documentary analysis: Documents related to the Delta Project, such as activity reports, strategic plans, and institutional policy documents, were reviewed in order to obtain additional information on its integration in the FAU and its alignment with sustainability objectives.

Participatory Observation: Visits to the Delta Project were carried out to observe ongoing activities, student participation and interaction between the different actors involved. These observations helped to contextualise the information gathered through interviews and documents.

Data analysis

Data analysis was conducted qualitatively, using a content analysis approach (Elo & Kyngäs, 2008; Neuendorf, 2017). Interviews, documents and observations were analysed to identify patterns, themes and trends related to the research objectives and indicators of the E-ULL-HEIs tool. Data were organised into relevant categories and comparisons were made to assess the integration of the Delta Project in the FAU, its alignment with sustainability objectives, and the challenges identified in relation to the quintuple helix.

How this method was applied to achieve the research objectives is detailed below:

Identification of Patterns, Themes and Trends:

Coding Process: This began with open coding, assigning labels to specific text segments drawn from interviews and documents, as well as detailed descriptions of observations. This allowed for the identification of emerging patterns without the constraint of a predefined framework.

Thematic Grouping: The generated codes were further grouped into broader themes reflecting the research objectives and indicators of the E-ULL-HEIs instrument. This grouping was crucial to synthesise the data and facilitate the identification of key trends in the integration of the Delta Project in the FAU and its alignment with the sustainability objectives.

Organisation of Data into Relevant Categories:

Categorisation: The coded and thematised data were organised into categories that corresponded to the specific indicators of the E-ULL-HEIs tool. These categories included

the assessment criteria defined in the tool.

Comparison and Contrast: Comparisons were made within and across categories to assess the consistency of findings and the depth of project integration and alignment with sustainability goals.

Assessment of Project Integration and Challenges:

Alignment Analysis: assessed how the Delta Project's activities and strategies aligned with the sustainability objectives set by the FAU and broader sustainable development goals.

Challenge Identification: Challenges related to the integration of the quintuple helix were specifically explored to understand the gaps and opportunities for collaboration between academia, industry, government, civil society and the environment.

Data triangulation (Denzin, 2017), involving the combined use of interviews, documentary analysis and direct observation, was employed to strengthen the validation of the data collected, thus minimising the inherent limitations of each individual method.

To ensure that observational data collection was as objective and systematic as possible, detailed observation guides were implemented along with specific protocols for recording events and behaviours. These standardised tools were crucial to maintain consistency in data collection between different observers and to ensure that all relevant aspects of the project were properly documented.

This method allowed observation of ongoing activities, facilitated understanding of interactions between students and other key project stakeholders, provided a richer and more detailed perspective that may have been difficult to capture through interviews and documentary analysis alone.

Ethical Considerations

Informed consent was obtained from all participants prior to conducting interviews and observations. Confidentiality of information was guaranteed and ethical principles of research were followed (Bhairappanavar et al., 2018; Sivasubramaniam et al., 2021).

Limitations of the Study

It is important to note that this study focuses on the in-depth analysis of a single case study, the Delta Project in Guayaquil, so the findings may not be generalisable to other contexts. However, it is hoped that the results contribute to detailed understanding of how ULLs can function as sustainable learning environments in the field of architecture and urbanism in challenging contexts, such as Guayaquil, conditioned by rapid urban growth and development needs.

The applied methodology allows to gain a holistic understanding of the integration of the Delta Project as a learning environment at FAU and its alignment with sustainability objectives and ESD, to visualize the complexity of its implementation, as well as to identify specific challenges related to the collaboration of the quintuple helix in this context.

Results

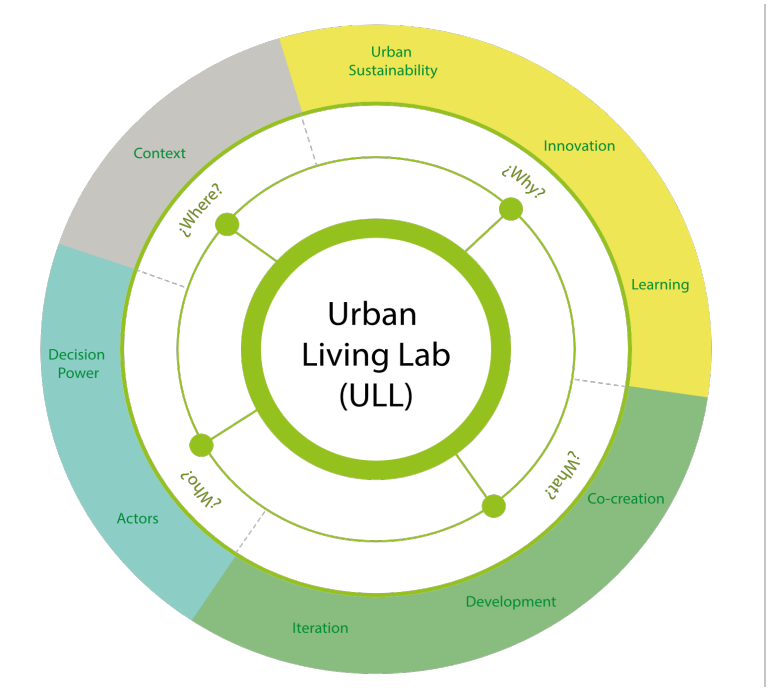
4.1. Integration of the Delta Project as a Learning Environment

This section presents the results derived from the evaluation of the Delta Project as a learning environment, using the E-ULL-HEIs tool. The findings obtained in the evaluation of each of the seven defined indicators are detailed below, followed by their corresponding numerical assessment, graphical representation and interpretation of the assessment.

4.1.1. Objectives and Scope

This project has been designed to answer the questions Why, What to do, Who and Where? This approach combines urban sustainability, innovation, co-creation, decision-making power, among other key factors, schematically represented in Figure 4.

Figure 4: **Factors considered in the Delta Project, based on Amsterdam Institute for Advanced Metropolitan Solutions (Amsterdam Institute for Advanced Metropolitan Solutions, 2019).**



This innovative urban development project seeks to meet the needs of the local community by creating a public space that not only complements, but also integrates with the existing community and educational facilities. The intention is to develop an urban environment that encourages new modes of mobility, provides green areas for rest and recreation, and creates safe and resilient spaces.

It is identified that the objectives of the Delta Project go beyond the mere construction of physical infrastructure; it aims to formalise knowledge in the field of ESD.

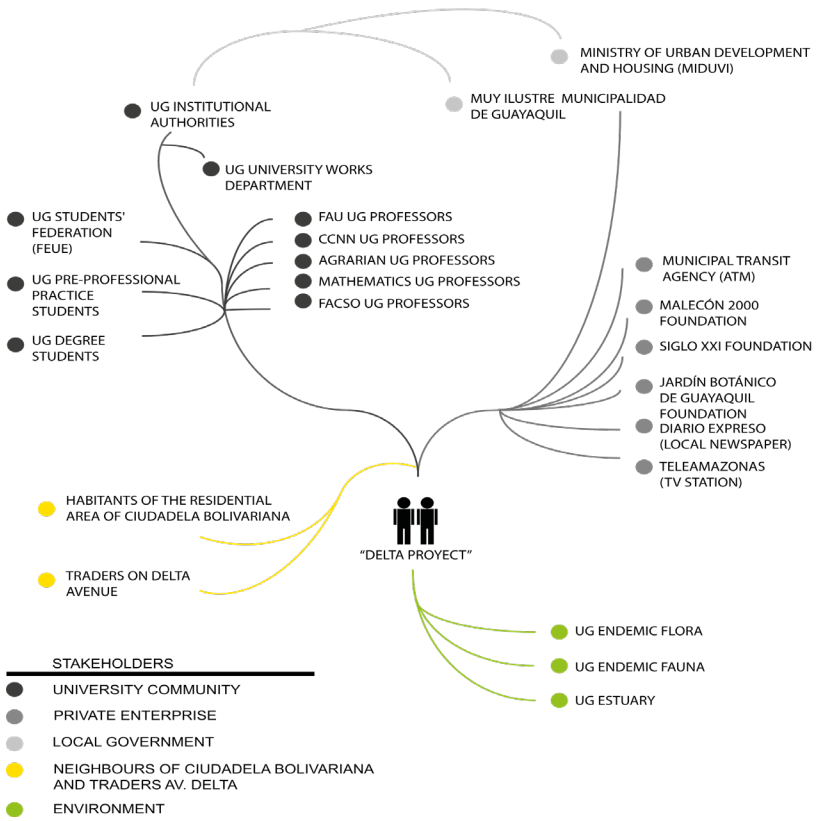
4.1.2. Participation and Interdisciplinarity

The Delta Project, characterised by its interdisciplinary and collaborative approach, has actively integrated teachers and students from various faculties of the University of Guayaquil, including Architecture (FAU), Natural Sciences (CNN), Agricultural Sciences, Mathematics (Civil Engineering) and Social Communication (FACSO). This joint effort has been strengthened with the participation of the Department of University Works and the institutional authorities of the university.

Student involvement, with a prominent role of the Federation of Students (FEUE) and students from different levels and specialisations of the Faculty of Architecture, has been an essential component. These students have contributed significantly, applying their academic knowledge in a practical and real context, which has enriched both their educational experience and the development of the project.

In addition, collaboration has extended to external entities and actors, including local residents and merchants, the Municipality of Guayaquil, the Ministry of Development and Housing (MIDUVI), the Municipal Transit Agency (ATM), foundations such as Siglo XXI and Malecón 2000, as well as the media. This diversity of participants has brought a wide range of perspectives and expertise, effectively addressing sustainability challenges on Delta Avenue, a real-life scenario that allowed for experimentation and co-creation. A representative schematic of this collaborative network is shown in Figure 5.

Figure 5: **Network of stakeholders Delta Project**
Red de participantes en "Proyecto Delta" según enfoque de la quíntuple hélice



4.1.3. Curricular Integration

The integration of the Delta Project with the academic curriculum at FAU has manifested itself as a transformative initiative, especially between 2017 and 2020, through a process of curriculum redesign and updating. This process has been notably influenced by the experiences and learnings of the Delta Project, with a special focus on sustainability.

As a result of this process, new subjects such as Entrepreneurship and Innovation and Sustainable Architecture have been integrated, significantly broadening the educational scope towards sustainability. Likewise, pre-existing subjects such as Bioclimatic Architecture and Sustainable Urban Development have been meticulously reviewed and updated to incorporate the latest advancements and address the current challenges in these areas. This effort has not only fostered interdisciplinary collaboration and curricular integration but has also facilitated the diverse and significant participation of a wide spectrum of stakeholders, ensuring that the Delta Project effectively meets local needs and contributes to sustainable development.

The implementation of the Master's in Sustainable Urban Development reinforces this vision, consolidating FAU's commitment to the principles of education for sustainable development. Such changes demonstrate the positive and lasting influence of the Delta Project in the realm of higher education, establishing it as a benchmark in the integration of sustainability into the educational curriculum.

Simultaneously, the Delta Project has become an invaluable research platform for the university, providing a real setting for the study and practical application of theories and practices related to urban sustainability.

4.1.4. Impact on learning and research

The impact of the Delta Project on learning and research at FAU has been highlighted by its innovative, interdisciplinary and sustainability-oriented approach. The implementation of the project has focused on a practical and applied approach, integrating user experience into the research and teaching processes. In particular, the project stood out for its impact on the FAU, especially in terms of its contribution to the teaching-learning process and the production of formalised knowledge. This has enriched architectural education with a sustainable approach. However, its effectiveness experienced a decline during the 2020 and 2021 periods, attributable to the challenges posed by the COVID-19 pandemic. Four well-defined blocks are identified in the project (Hugo et al., 2018).

Project Management and Administration: involved an interdisciplinary group of specialists from various faculties of the University of Guayaquil, collaborating with representatives of the municipality, private enterprise and the community. This block focused on innovation, socialisation and dissemination of the project.

Knowledge Integration: here, students participated through pre-professional internships, final degree projects and the project workshop, applying a transdisciplinary, experiential and adaptive (TEA) approach to learning. This integration fostered collaboration between multiple actors, including the community and the private sector.

Professionalisation: Specialised and multidisciplinary forums were held, covering areas such as technology, ecology, urbanism and sustainability. These forums provided

spaces for the exchange of knowledge and fostered the professional development of students, the most relevant of which are listed in Table 1.

Table 1. **List of the most relevant specialised and multidisciplinary forums**

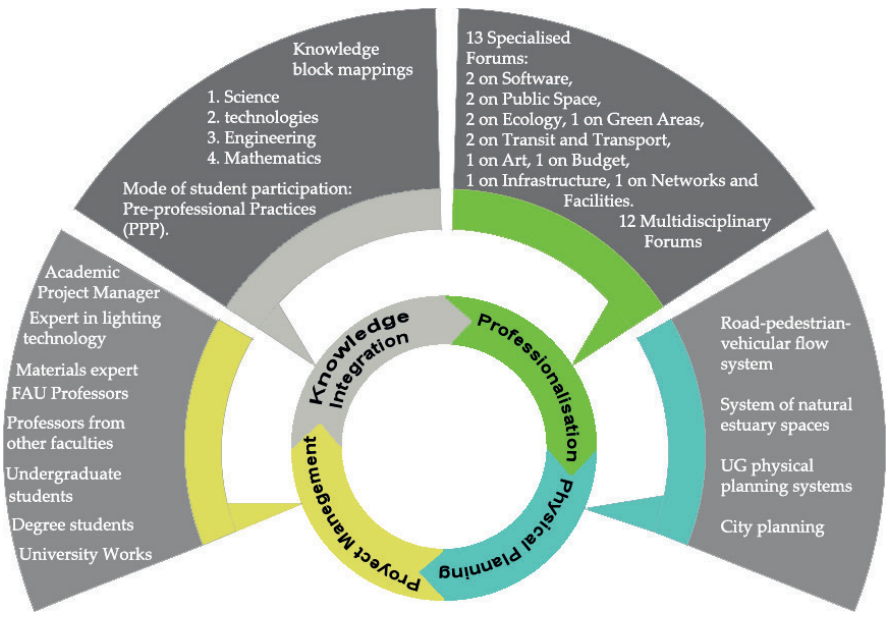
Forum name	Participants	Organisers
Inter-university forum: 1st zonal meeting of Faculties of Architecture and Urbanism: Guayaquil Bicentenary, a look into the future, Laica version.	Architecture students, teachers, architects and engineers, Delta Project Researchers.	Faculty of engineering, industry and construction, Universidad Laica Vicente Rocafuerte; Faculty of Architecture and Urbanism, UG; Faculty of Architecture and design, Espiritu Santo University; Faculty of Architecture and design, Santiago de Guayaquil Catholic University.
Inter-university forum: 2nd zonal meeting of Faculties of Architecture and Urbanism: Guayaquil Bicentenary, a look into the future, UG version.	Architecture students, teachers, architects and engineers, Delta Project Researchers.	Faculty of engineering, industry and construction, Universidad Laica Vicente Rocafuerte; Faculty of Architecture and Urbanism, UG; Faculty of Architecture and design, Espiritu Santo University; Faculty of Architecture and design, Santiago de Guayaquil Catholic University.
The road network of Ciudadela Bolivariana.	Architecture students, teachers, Delta Project Researchers.	Faculty of Architecture and Urbanism, UG; Municipal Transit Agency (ATM).
Public transport on Delta Avenue.	Architecture students, teachers, Delta Project Researchers.	Faculty of Architecture and Urbanism, UG; Municipal Transit Agency (ATM).
Tree species in mangrove areas.	Architecture students, natural sciences students, agrarian students, teachers, Delta Project Researchers.	Faculty of Architecture and Urbanism, UG; Botanical Garden Foundation of Guayaquil
Precast permeable concrete pavers.	Architecture students, teachers, Delta Project Researchers.	Faculty of Architecture and Urbanism, UG; Hormipisos, concrete pavers company
Native vegetation in the UG.	Architecture students, natural sciences students, agrarian students, teachers, Delta Project Researchers.	Faculty of Architecture and Urbanism, Faculty of Agricultural Sciences, UG
The Ug estuaries and their relationship with their inhabitants.	Architecture students, natural sciences students, agrarian students, teachers, Delta Project Researchers.	Faculty of Architecture and Urbanism, Faculty of Natural Sciences, UG
The use of software in the project: application of pedestrian simulators.	Architecture students, students of Mathematical and Physical Sciences, teachers, Delta Project Researchers.	Faculty of Architecture and Urbanism, Faculty of Mathematics and Physics, UG
Urban planning regulations for public space developed by Jan Gehl.	Architecture students, students of Mathematical and Physical Sciences, teachers, Delta Project Researchers.	Department of University Works
Municipal urban planning regulations.	Architecture students, students of Mathematical and Physical Sciences, teachers, Delta Project Researchers.	Department of University Works
Ordinances of the land-use plan.	Architecture students, students of Mathematical and Physical Sciences, teachers, Delta Project Researchers.	Department of University Works
Traffic regulations.	Architecture students, students of Mathematical and Physical Sciences, teachers, Delta Project Researchers.	Department of University Works

Annexes 5a, and 5b of the POT of Guayaquil.	Architecture students, students of Mathematical and Physical Sciences, teachers, Delta Project Researchers.	Department of University Works
ASSTHO norms.	Architecture students, students of Mathematical and Physical Sciences, teachers, Delta Project Researchers.	Department of University Works
Urban infrastructure in the UG and its surroundings	Architecture students, students of Mathematical and Physical Sciences, teachers, Delta Project Researchers.	Department of University Works
Lighting up the streets	Architecture students, students of Interior Design, teachers, Delta Project Researchers.	Faculty of Architecture and Urbanism, UG; Integral Iluminación, Lighting, audio, video and domotics company.
Photogrammetry with drones	Delta Project Researchers.	Faculty of Architecture and Urbanism, UG; Ecuadrones.

Physical Planning: this block allowed students to apply their technical skills in architectural design and software handling, providing relevant practical experience.

Each block contributed to holistic learning, where students not only acquired technical knowledge, but also developed skills in collaboration, critical thinking and problem solving, preparing them for real-world challenges in their future careers. The implementation of these blocks in the Delta Project has had a significant impact on enriching learning and research at FAU. A representation of the structure of the blocks is presented in Figure 6.

Figure 6: **Process Blocks Delta Project**



Practical experience and adaptability have emerged as crucial elements in equipping students to address contemporary architectural challenges, underscored by the project's significant contributions, including four final projects, a master's thesis, a scientific publication, a scientific poster, and two presentations at international congresses. These accomplishments highlight the project's positive influence on the academic and professional landscape. However, it's essential to acknowledge that the project's effectiveness encountered a decrease during 2020 and 2021, attributable to the constraints and hurdles presented by the COVID-19 pandemic.

4.1.5. Community Impact

The project has actively encouraged diversification and the participation of a wide spectrum of stakeholders, including governmental institutions at both municipal and state levels, private foundations, members of the university community, local residents, traders, as well as the integration of the surrounding natural systems, contributing to interdisciplinarity and curriculum integration in sustainability education. It has also been fundamental in the creation of new public spaces and the development of more efficient and sustainable mobility systems for the community. The Delta project has significantly contributed to the well-being and sustainable development of the local community, transforming sustainable mobility through the implementation of cycle lanes, the expansion of pavements, and improved accessibility. This approach has promoted the use of cleaner and more efficient transport, thereby improving public health and reducing congestion. Inclusive designs have ensured equity in access, fostering social cohesion and strengthening the sense of community among residents. Furthermore, the incorporation of green areas has enhanced the environment, reduced pollution, and promoted biodiversity, highlighting the importance of urban planning that prioritises environmental sustainability (Seis, 2023).

4.1.6. Resources and Sustainability

The institution's available funding has been efficiently used to develop an urban-architectural project of significant relevance to the community. This includes the allocation of competitive internal funds amounting to USD 7,890.13, which facilitated the dissemination of the project across various scientific platforms. The contribution of these professionals has allowed not only the realisation of the project but also its adaptation to the specific needs and academic culture of the university.

However, a crucial aspect that has led the project to become a tangible reality is the management and funding provided by the municipality. This additional support has been instrumental in overcoming the initial financial challenges and ensuring the viability of the project.

Regarding the adaptability of the Delta Project model, it is imperative to stress the importance of careful customisation to ensure its relevance and effectiveness in different scenarios. This implies adapting the model to the particularities of the academic culture and urban needs of the context in which it is implemented, thus ensuring that the project effectively responds to local demands.

To achieve long-term sustainability of the Delta Project, it is necessary to focus on strategic planning that includes assessing sustainable funding sources in new contexts. This planning must consider not only the immediate financial needs but also how the project will be maintained and evolve in the future, ensuring its continued impact and relevance.

The combination of a strategic approach to fund management and careful adaptation to local needs is essential to successfully replicate this model in other contexts.

In the following, the findings derived from the evaluation of the ULL Delta Project, implemented as a pedagogical instrument, are disclosed through the application of the indicators provided by the E-ULL-HEIs tool. Table 2 summarises the evaluative

parameters corresponding to each indicator, the assignment of ratings based on specific criteria, supported by evidence collected through interviews, surveys and documentary analysis related to the project. Additionally, the rating of each indicator is presented, as well as the overall score attributed to the ULL. This systematisation of the evaluation seeks to contribute to a comprehensive understanding of the effectiveness of the project as a teaching resource, emphasising the rigour and objectivity inherent in scientific analysis.

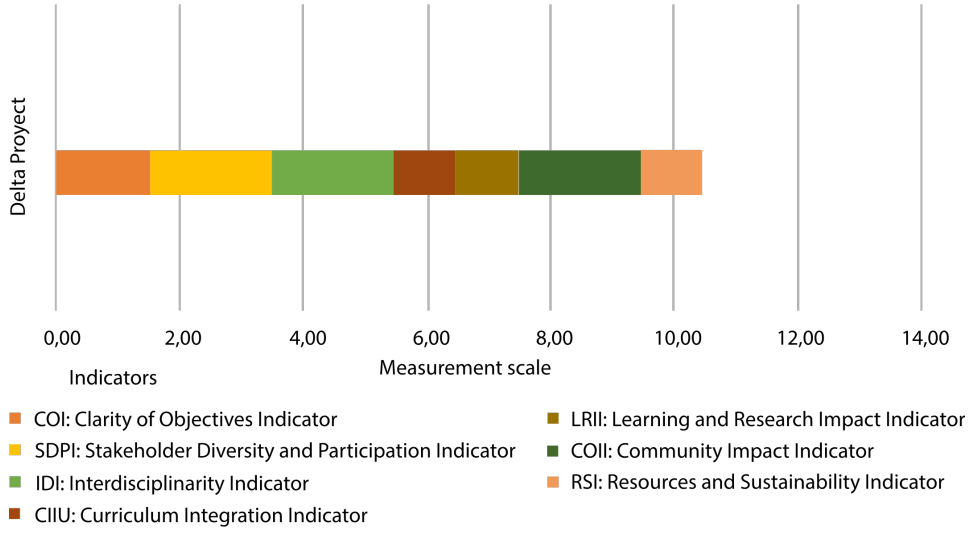
Table 2. **Overall Delta Project evaluation results**

Indicator	Criteria	Assessment			Criteria Score	Indicator Score
		Low (0)	Moderate (1)	High (2)		10,50
COI	Clarity of Objectives	Objectives unclear and ambiguous.	Objectives moderately clear	Objectives completely clear	2,00	1,50
	Alignment with ESD	Objectives not aligned	Partially aligned targets	Objectives fully aligned	1,00	
SDPI	Stakeholder diversity	Lack of diversity, limited and homogeneous actors	Some diversity of actors	Maximum diversity	2,00	2,00
	Degree of Involvement	Minimal involvement	A higher degree of involvement	Active participation	2,00	
IDI	Diversity of disciplines per project	No diversity of disciplines	Low diversity of disciplines	High participation of disciplines	2,00	2,00
CIIU	Level of Curricular Integration	No programmes address activities related to the project	Moderate integration of project activities into the HEI curriculum	project activities are actively integrated into the HEI curriculum	1,00	1,00
LRII	Skills Development	Students have experienced limited development of sustainability-related skills	Students have developed sustainability-related skills to some extent, but not fully	Students have experienced significant development of sustainability-related skills	1,00	1,00
	Publications and Presentations	Research results have not been published	Research results have been published in a limited number	Research results have been widely disseminated in academic journals	1,00	

COII	Improved Quality of Life	The activities have not had a significant impact on the quality of life of the community.	The project actions have contributed to some extent to a better quality of life in the community.	The project activities have had a significant impact on the quality of life in the community.	2,00	2,00
	Reduction of Environmental Impacts	No efforts to manage natural resources are observed.	There may be limited efforts to promote sustainable management of natural resources	the activities have had a significant impact on reducing negative environmental impacts	2,00	
RSI	Efficiency in the Use of Resources	The results and benefits achieved do not justify the level of resources used.	Project has achieved some efficiency in the use of resources	It has demonstrated high efficiency in the use of financial resources.	2,00	1,00
	Promotion of Sustainable Practices	The promotion of sustainable practices in the project is minimal	The project has promoted at least two sustainable practices.	The project has effectively promoted more than two sustainable practices.	0,00	

Figure 7 and 8 show the graphical representation of the evaluation results.

Figure 7. **Results of the comprehensive evaluation of the Delta Project**



The Delta Project has demonstrated a significant alignment with the indicators of the E-ULL-HEIs evaluation tool, the result obtained through the E-ULL-HEIs evaluation tool is 10.5, placing it in the range of interpretation of the tool between 8 and 11, suggesting that the project is achieving satisfactory results with respect to ESD. The interpretation and analysis of the results for each of the indicators is presented below.

COI: With a score of 1.50, this indicates that the project objectives are completely clear and partially aligned with Education for Sustainable Development (ESD) principles, however, the sustainability elements are not comprehensively addressed. This suggests that the project is on track with opportunities for improvement to ensure that activities and outcomes focus on clear sustainable goals that positively impact the teaching-learning process and formalised knowledge production at FAU.

SDPI: Achieves the maximum score of 2.00 for stakeholder diversity and degree of involvement, suggesting a diverse participation of stakeholders in the project, a crucial aspect for the successful implementation and acceptance of sustainable solutions.

IDI: With a score of 2.00, it reflects a diversity of disciplines involved in the project holistically addressing sustainability challenges. Interdisciplinarity is reflected in the collaboration of specialists from different faculties and the integration of applied knowledge in a practical and real way, enriching the educational experience and the development of the project.

CIIU: The score of 1.00 indicates a moderate integration of project activities into the HEI curriculum. This suggests that, although there are efforts to integrate the project into teaching and learning, there are opportunities to strengthen this integration.

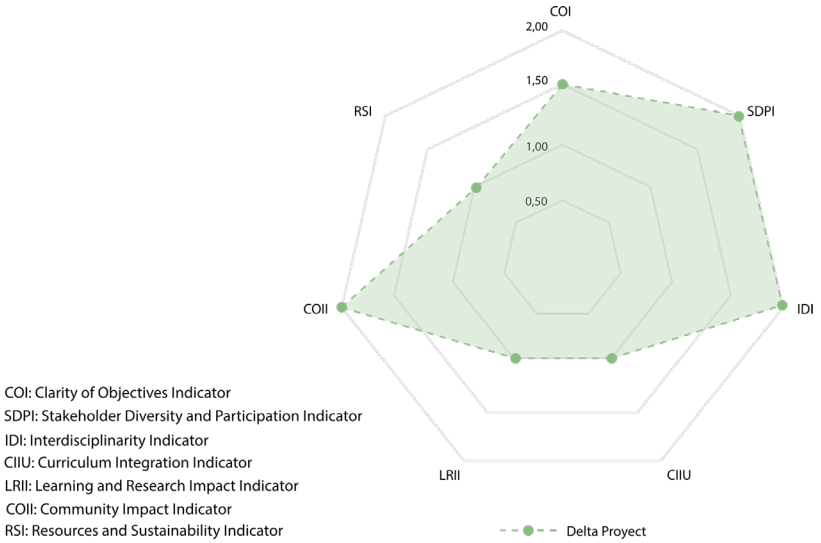
LRII: Scores 1.00, reflecting progress in the development of sustainability-related skills among students, as well as in the generation of scientific output. This result suggests that, although the project has contributed to the promotion of sustainability competences, the depth and breadth of these skills, as well as the volume and scope of related scientific output, have not yet reached their full potential. The need to strengthen these aspects is recognised, which is strongly related to the CIIU indicator.

COII: Reaches the maximum score of 2.00, which indicates a positive impact on the quality of life and the reduction of negative environmental impacts on the community. These results are clear examples of the beneficial effects of the project at both the educational and community levels. The project has promoted the creation of new public spaces and the development of more efficient and sustainable mobility systems for the community, becoming an invaluable research platform for the university and contributing significantly to the well-being and sustainable development of the local community.

RSI: With a resource efficiency score of 1.00, the project demonstrates some efficiency, but with room for improvement. However, the project did not promote additional sustainable practices, which is an area for future development.

The overall assessment reflects a strong performance of the Delta project in several key aspects of sustainability and ESD, especially in clarity of objectives, stakeholder engagement, learning and research impact, and community impact. However, it identifies areas for improvement such as alignment with economic sustainability, deeper curriculum integration, as well as promotion of additional sustainable practices. These results provide an important basis for reflection and continuous improvement of the project, aligning with the objectives of promoting effective and tangible sustainable development through education and community engagement.

Figure 8: **Graphical representation of the indicators of Delta Proyect**



4.2. *Challenges in the Quintuple Helix Collaboration*

The incorporation of the quintuple helix into the Delta Project at the University of Guayaquil involved overcoming several significant challenges. These challenges centred on interdisciplinary integration and effective collaboration between academia, business, government, civil society and the environment. The project faced obstacles related to funding and resources, especially in a context of budgetary constraints.

To address these challenges, an interdisciplinary team was formed that included faculty and students from different faculties, as well as representatives from the municipality and private enterprise. This team actively collaborated in the design and implementation of innovative and sustainable strategies. In addition, the local community was involved in the project, overcoming initial resistance and transforming it into an opportunity for inclusive dialogue and participatory decision-making.

The project also benefited from the formalisation of an inter-institutional agreement between the University and the Municipality of Guayaquil, securing significant funding. This financial support was crucial for the implementation of multidisciplinary activities, the realisation of specialised forums and the integration of education into the project, aligning activities with curricular content and allowing for an effective evaluation of student contributions.

The effectiveness of the ULL model at the UG also faces institutional challenges, especially due to the instability of university authorities influenced by the political dynamics of the country. This situation is compounded by the lack of appropriate legal frameworks to facilitate collaborative projects that effectively respond to local needs and realities. These challenges underline the need for a more stable and adapted approach at institutional level to maximise the potential of ULLs in the university context.

Discussion

The evaluation of the Delta Project, through the E-ULL-HEIs tool, shows alignment with its indicators, implying that the project has achieved significant results as a strategy

for ESD in HEIs. However, further research on how this acquired knowledge translates into practical skills and real-world applications is essential. Furthermore, it would be beneficial to explore the long-term impact of the project on the local community and urban environment.

The Delta Project model presents significant potential for adaptation and replication in other educational institutions. However, it is crucial to consider variations in available resources, academic culture and specific urban needs. Discussing scalability involves addressing both the financial and human resources needed and strategies for adapting the project to different academic environments and cultures.

While ULLs such as the Delta Project show promise for integrating sustainability into education, they face challenges such as long-term financial sustainability and managing multi-stakeholder expectations. A critical perspective on these challenges can provide a more balanced understanding of ULLs and suggest improvements in the planning and implementation of future projects.

One of the keys to the success of projects such as the Delta Project is the active and meaningful participation of students. Addressing challenges in this area, such as curricular integration and fostering student engagement, is essential to maximise the educational and practical benefits of ULL. Innovative strategies to increase student participation and the relevance of these projects to their academic training are critical.

The analysis of several ULLs employing similar methods to the Delta Project reveals diverse approaches to sustainability and urban innovation. To reinforce the Delta Project's case study methodology and provide a comparative framework, several key ULLs have been identified:

Innovation Platform Malmö, Sweden, a project that engages municipal, business, academic and community actors in the renovation of existing apartment buildings to achieve high energy and sustainability standards. It uses learning methods based on discovery, interaction and experimentation, enabling a deep dive into urban sustainability. Like the Delta project, it encourages co-creation and active community participation, involving diverse stakeholders in the innovation process from the outset. However, they differ in that Malmö focuses specifically on the renovation of existing buildings, while the Delta project addresses aspects of public space and its approach to urban sustainability and sustainable education.

The University of Manchester, UK, transforms the university campus into a living laboratory for sustainability science, where lessons and research are applied to real sustainability challenges, promoting the co-production of knowledge and innovative solutions. Like the Delta Project, both use existing infrastructure (university campuses or housing developments) as a platform for applying and testing sustainability solutions. However, the Delta Project could seek to incorporate new technologies, similar to the Manchester approach, to increase the relevance and educational impact of its activities.

Both Suurpelto and Lavras emphasise the importance of interdisciplinary approaches. Both Suurpelto and Lavras stress the importance of interdisciplinary approaches. The Delta Project, like Suurpelto and Lavras, with strengths in citizen participation and interdisciplinarity, could further strengthen its methodology by encouraging closer collaboration between different academic disciplines, reflecting the integrated approach that has been successful in these projects.

Inspired by Suurpelto, increasing community involvement in the Delta Project could improve the practical outcomes and social relevance of its initiatives, ensuring that projects address real-world challenges effectively. Following Lavras' example, the Delta Project could implement metrics to assess the environmental impact of its initiatives, providing quantifiable data to support the effectiveness of its sustainability efforts.

The Delta Project, as a ULL focused on sustainable education, faces challenges and limitations inherent to these innovative spaces. Based on these analyses, we identify crucial elements that can improve the effectiveness of projects such as Delta and ULLs in general.

Governance and institutional policy barriers: A relevant study identified governance barriers affecting sustainable performance, including a lack of information sharing and stakeholder support (Palazzo, 2020). This underlines the need for greater collaboration and institutional support in the Delta project to promote social sustainability.

Inclusive stakeholder engagement: ensuring that all relevant stakeholders are involved in the innovation process from the beginning, similar to the Malmö Innovation Platform.

Applied teaching and research: harnessing university resources to address real-world problems, as seen in Manchester, can enhance the impact and relevance of the Delta Project. Tools such as Process Wheels and MIT's Learning Adventure Card demonstrate how ULL can foster leadership and creative problem-solving skills (Wolff, 2020).

Integrating sustainable development skills: Architecture and urbanism education must integrate sustainable development skills through innovative learning methodologies. Living Labs, such as LOW3 at ETSAV, show how renewable energy projects can be effective tools for this purpose.

Iterative learning and adaptation: adopt a flexible approach to project implementation, allowing for continuous adjustments based on feedback and emerging results, similar to the strategies employed in Lund.

Proven strategies for stakeholder engagement, practical application of research and adaptive project management strengthen the Delta Project and ensure stronger implementation of urban sustainability initiatives.

Conclusions

The Delta Project, implemented at the FAU of the UG, has proven to be an effective tool to promote ESD. This study has shown how the application of a multidisciplinary approach and collaboration between academic, governmental, industry, civil society and environmental actors, essential in the five-fold helix model, are crucial to address complex urban and educational challenges.

Through the E-ULL-HEIs tool, the Delta Project performance was evaluated, highlighting its positive impact on stakeholder diversity and participation, interdisciplinarity, curricular integration, and learning and research. These results not only underline the relevance of the project in promoting sustainable practices, but also demonstrate its capacity to effectively integrate the SDGs into FAU's education and operations.

The Delta Project has faced significant challenges, from cross-sectoral collaboration to active student participation, highlighting the importance of overcoming barriers in

curriculum integration and student engagement to amplify the impact of these innovative spaces in education.

These comparable experiences reveal similar challenges, even when oriented towards promoting sustainability and innovation, as is the case with the projects of the Malmö Innovation Platform, the University of Manchester, the Federal University of Lavras and the ULL in Suurpelto, which share similar challenges focused on promoting sustainability and innovation. Both Malmö and Manchester have identified obstacles such as dependence on external funding and the need for constant institutional support. The Federal University of Lavras, acting as a living laboratory, has implemented sustainable initiatives ranging from water and energy management to transport, facing challenges such as community engagement and the need for ongoing support to maintain and expand their projects. In Finland, Suurpelto highlights the importance of students as innovators, yet integrating their projects in a sustainable way and maintaining their relevance and engagement over the long term represents a significant challenge.

This study highlights how ULLs such as the Delta Project can serve as a model for other educational institutions seeking to integrate sustainability into their curricula. The results suggest that the project has had a positive impact on stakeholder diversity and participation, interdisciplinarity, curricular integration, as well as learning and research. This transdisciplinary, experiential and adaptive approach (TEA approach) (Engels & Walz, 2018; Palazzo, 2019; Palazzo & Shirleyana, 2022), has made it easier for students to not only learn about sustainability and urban development concepts in theory, but also apply and experience them in real and practical contexts. These results not only validate the relevance of the Delta Project in promoting sustainability, but also highlight its ability to effectively integrate the SDGs into FAU education.

Strengthening institutional collaboration and support is essential to overcome governance challenges and promote flexible adaptability and evaluation in the face of change. Active student participation and curricular integration are vital to the success and practical impact of projects such as Delta. Furthermore, it is suggested that future research should explore the adaptation of ULL models in different geographical and cultural contexts, assessing their effectiveness in promoting ESD.

This means that the implementation of the Delta Project has fostered a methodological shift in which students are directly involved in projects that impact and improve their immediate environment. This active, student-centred methodology promotes a deeper understanding of contemporary urban challenges and equips future architects with the tools to address these challenges in innovative and sustainable ways.

In addition, the Delta Project has strengthened collaboration between students, professors and various urban actors, which has enhanced the learning dynamic and increased the relevance of FAU as a centre of innovation in urban sustainability. The transdisciplinary nature of the project has encouraged students to work beyond the traditional constraints of architecture, integrating knowledge from environmental sciences, engineering and social sciences, reflecting a more holistic architectural education adapted to the challenges of the 21st century.

In terms of academic and community impact, the Delta Project has demonstrated how educational interventions focused on sustainability can lead to tangible improvements in the community, strengthening students' civic engagement and their capacity to act

as agents of change in their future professional careers. Through this project, FAU has established an educational model that not only responds to contemporary educational demands, but also actively contributes to urban sustainability.

Future research could develop or improve evaluation tools to more accurately and holistically measure the impact of ULL on education and the community. This case study of the Delta Project not only enriches the existing literature on ULLs and sustainable education, but also lays a solid foundation for exploring new dimensions of research that can contribute significantly to the field of sustainable urban development and educational innovation.

With the right institutional support and further alignment with academic goals, ULLs can become key tools to prepare students to meet the sustainability challenges of the future.

Finally, continuous and detailed evaluations of related projects are recommended to better understand their long-term impact and improve their effectiveness. Adapting educational initiatives in different contexts requires taking into account the diversity of resources, academic culture and specific needs. It is also crucial to address financial sustainability and stakeholder expectations to enrich the development of future projects.

Strengthening collaboration and institutional support is essential to overcome governance challenges and to promote flexible adaptability and evaluation in the face of change.

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