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# Integrating science, technology, and experimental knowledge for sustainable innovation: A Living Lab approach to urban biodiversity management

***Marta Najda-Janoszka*[1], *Joanna Kajzer-Bonk*[2]**
***Ewelina Milewska*[3], *Sylwia Wrona*[4]**

***Abstract***

***PURPOSE:*** *This study aims to enhance understanding of STI (Science, Technology, Innovation) and DUI (Doing, Using, Interacting) integration dynamics in sustainable innovation, specifically investigating its role in innovation outcomes, stakeholder engagement, and the institutionalization of sustainable practices in urban lawn management.* ***METHODOLOGY:*** *Using a single case study design, the study captures real-time, dynamic interactions between STI and DUI practices, observing ongoing processes. Data were collected through five focus group interviews with 32 stakeholders, individual interviews, project documentation, and a project diary. Stakeholders included public sector officials, NGOs, private garden owners, and business representatives, each offering insights into policy, environmental practices, and market-driven solutions. The Living Lab methodology, emphasizing co-creation and iterative feedback, guided both data collection and analysis, with NVivo software and manual coding used to identify key themes and challenges in integrating STI and DUI for sustainable innovation.* ***FINDINGS****: The investigation revealed that integrating STI and DUI modes fosters a dynamic synergy: STI provided scientific rigor, while DUI leveraged stakeholder input and local contexts to co-develop adaptive urban biodiversity solutions. This approach addressed location-specific challenges, balancing ecological goals with practical feasibility. For instance, stakeholder engagement refined scientific recommendations, ensuring broader applicability and adoption. Despite tensions between rigor and practicality, the participatory Living Lab methodology facilitated co-creation, aligning scientific insights with real-world needs to enhance sustainable lawn care practices.* ***IMPLICATIONS****: The study contributes to innovation theory by showing how integrating STI and DUI modes fosters socially responsive, adaptable solutions for urban biodiversity management. From a practical standpoint, it underscores the importance of stakeholder engagement in developing tools and strategies that balance scientific insights with practical, real-world application. The project offers a replicable model for integrating formal research with user-driven innovation in sustainability projects.* ***ORIGINALITY AND VALUE:*** *This paper provides a unique contribution by showcasing how the integration of formal scientific research (STI) with practical, user-cantered approaches (DUI) can foster* **innovability***. The use of the Living Lab methodology to co-create urban biodiversity solutions bridges the gap between academic research and practical application, offering a novel framework for addressing complex environmental challenges through collaborative innovation.*

***Keywords:*** *sustainable innovation, Science, Technology, Innovation, STI, Doing, Using, Interacting, DUI, urban biodiversity, lawn management, Living Lab, stakeholder engagement, participatory innovation, co-creation, climate change adaptation*

1 Marta Najda-Janoszka, Ph.D. Hab., Associate Professor, Jagiellonian University, Faculty of Management and Social Communication, prof. St. Łojasiewicza 4, 30-348 Krakow, Poland, e-mail: marta.najda-janoszka@uj.edu.pl (ORCID: https://orcid.org/0000-0002-5040-7250).

2 Joanna Kajzer-Bonk, Ph.D, Assistant Professor, Jagiellonian University, Faculty of Biology and Earth Sciences, Gronostajowa 9, 30-387 Kraków, Poland, e-mail: joanna.kajzer@uj.edu.pl (ORCID: https://orcid.org/0000-0003-4063-2785).

3 Ewelina Milewska, M.A., Assistant, Jagiellonian University, Faculty of Management and Social Communication, prof. St. Łojasiewicza 4, 30-348 Kraków, Poland, e-mail: e.milewska@uj.edu.pl (ORCID: https://orcid.org/0000-0002-3957-1447).

4 Sylwia Wrona, Ph.D., Assistant Professor, Jagiellonian University, Faculty of Management and Social Communication, prof. St. Łojasiewicza 4, 30-348 Kraków, Poland, e-mail: sylwia.wrona@uj.edu.pl (ORCID: https://orcid.org/0000-0003-1881-0370).

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## INTRODUCTION

Innovability, the synergy of innovation and sustainability, emerges as a transformative approach to tackling complex global challenges by ensuring that technological advancements are environmentally responsible and socially inclusive (De La Vega Hernández & Barcellos de Paula, 2021). This concept advocates for innovations that move beyond traditional economic growth, instead driving sustainable development by prioritizing environmental integrity and social well-being (Adams et al., 2016). It ensures that technological advancements contribute not only to economic progress but also to long-term ecological sustainability and social benefits (Adams et al., 2016). Despite its potential, the practical realization of innovability remains underexplored, particularly in how different innovation modes can be integrated to achieve sustainable outcomes.

The integration of Science, Technology, and Innovation (STI) with Doing, Using, and Interacting (DUI) modes offers a promising pathway to operationalize innovability. The STI mode emphasizes formal knowledge creation through structured research and development, leading to technological advancements disseminated via products, processes, or services (Jensen et al., 2007; Nunes & Lopes, 2015). In contrast, the DUI mode relies on tacit knowledge and experiential learning, emphasizing practical experience, iterative feedback, and stakeholder engagement (Marzucchi & Montresor, 2017; Jensen et al., 2007). Combining these modes can enhance innovation outcomes by merging structured knowledge with practical adaptability, fostering solutions that are both technologically advanced and responsive to real-world needs (Beynon et al., 2024; Carrillo-Carrillo & Alcalde-Heras, 2021).

However, achieving this integration is complex and fraught with challenges, such as internal conflicts and inefficiencies, especially in contexts where formal research and operational practices are traditionally siloed (Parrilli & Elola, 2012; Marzucchi & Montresor, 2017). Existing studies remain inconclusive on whether STI and DUI modes complement or substitute one another (Najda-Janoszka, 2025). Some argue that combining them enhances innovation, enabling organizations, public institutions, and social communities to benefit from both formal research and practical adaptability (Lundvall et al., 2009; Fitjar & Rodríguez-Pose, 2013). Others underscore the importance of contextual and temporal factors in shaping their combined effectiveness (Beynon et al., 2024). For instance, STI's focus on scientific rigor conceptually complements DUI's emphasis on flexibility, but their practical integration often depends on regional resources and long-term innovation performance outcomes (Beynon et al., 2024; Piercey et al., 2025; Parrilli & Elola, 2012). Research further highlights that the interplay between these modes is influenced by geographic and temporal factors, with peripheral regions favoring DUI-driven approaches and core regions leveraging STI modes for structural innovation performance (Beynon et al., 2024; Piercey et al., 2025). Further, firms pursuing integration of innovation modes face additional risks, such as "over-searching", which generates more ideas than they can absorb, thereby limiting their ability to act effectively (Haus-Reve et al., 2019). Moreover, integrating tacit, experience-based supply-chain knowledge with codified scientific knowledge is highly sector-specific and complicated by differences in innovation speeds and time horizons (Haus-Reve et al., 2019; Beynon et al., 2024; Simms & Frishammar, 2024). These challenges are exacerbated by fundamental knowledge asymmetries, which create communication barriers and a lack of shared understanding between collaborators (Simms & Frishammar, 2024). Ultimately, these insights underscore that achieving innovability through integration of STI and DUI requires nuanced, tailored strategies that account for the socio-economic, sectoral, and spatial dynamics of the target context.

The integration of STI and DUI modes offers a transformative approach to tackling the complexities of urban biodiversity management. As cities expand, the pressures of habitat fragmentation, infrastructure development, and competing land use demands threaten biodiversity, which is vital for ecosystem services such as air purification, temperature regulation, and flood control (Biella et al., 2025; Genovese et al., 2023). These challenges are further complicated by the diverse and often conflicting interests of stakeholders, including government agencies, private entities, NGOs, and local communities (Kopnina et al., 2024). Managing urban biodiversity effectively requires bridging scientific rigor with practical, experience-based solutions, enabling context-specific strategies that address ecological, social, and economic dimensions. Evidence-based practices, such as reduced mowing regimes, exemplify this balance by enhancing biodiversity and mitigating urban heat. However, broader adoption is limited by challenges like public perceptions, operational barriers, and integration into urban planning frameworks (Watson et al., 2020; Biella et al., 2025). These challenges highlight the need for approaches that not only generate knowledge but also ensure its application in real-world contexts.

In this context, the "To Mow or Not to Mow?" project selected as the case study for this research demonstrates how integrating STI and DUI modes can foster innovability in urban biodiversity management. Conducted at Jagiellonian University's Campus Living Lab, the project addresses biodiversity loss caused by conventional lawn-mowing practices,

which often prioritize aesthetic and administrative considerations over ecological benefits (Biella et al., 2025). The Living Lab methodology is scientifically relevant due to its epistemological foundations, which position it as both a tool for knowledge creation and a mechanism for validating that knowledge through real-world application (Verhoef et al., 2019). By combining formal research with community-driven engagement, Living Labs enable iterative co-creation (Stuckrath et al., 2025). This ensures that solutions are grounded in scientific rigor while remaining relevant to stakeholders. In this project, the Living Lab methodology is used to co-create sustainable lawn management practices with a diverse range of stakeholders, including local residents, public authorities, NGOs, and private sector representatives. This participatory approach ensures that solutions are not only ecologically sound but also socially accepted and practically applicable. Local residents provide experiential knowledge about community needs and preferences, public authorities offer regulatory guidance, NGOs contribute environmental expertise, and private sector representatives bring practical, market-driven insights. Through the engagement of these diverse parties, the Living Lab methodology fosters the development of sustainable lawn management practices that are both scientifically rigorous and tailored to the local context (Stuckrath et al., 2025).

The study aims to enhance the understanding of how the integration of STI and DUI modes can foster innovability in sustainable urban biodiversity management. Specifically, it seeks to explore how this integration affects innovation outcomes, stakeholder engagement, and the institutionalization of sustainable practices, with a particular focus on urban lawn management. To achieve this aim, the study has two main objectives: (1) to analyze how the integration of STI and DUI modes enhances innovation outcomes, stakeholder engagement, and the adoption of sustainable practices in urban biodiversity management; and (2) to identify the key tensions and challenges encountered in this integration and propose strategies for addressing them. These objectives are investigated through three research questions (RQs):

RQ1: How can the integration of STI and DUI modes facilitate innovability in urban biodiversity projects?
RQ2: What are the main tensions and challenges encountered in this integration, and how can they be managed?
RQ3: How does stakeholder engagement influence the innovation process and the institutionalization of sustainable practices?

The paper proceeds by first reviewing pertinent literature on innovability and the integration of STI and DUI modes, establishing the theoretical framework for the study. Following this, the methodology outlines the case study approach, data collection methods, and analytical procedures used to investigate the "To Mow or Not to Mow?" project. The findings present the results of the analysis, highlighting the dynamics of integrating innovation modes and their impact on project outcomes. The discussion interprets these findings in light of existing theories, identifying contributions to the literature and implications for practice. Finally, the conclusion summarizes the key insights, addresses limitations, and suggests directions for future research.

## LITERATURE REVIEW

The concept of "innovability" bridges innovation and sustainability (De Tomasso & Pinsky, 2022), extending earlier frameworks such as eco-innovation, sustainable business models, and shared value (Pereira et al., 2025; Bocken et al., 2014; Porter & Kramer, 2011). Unlike prior approaches that often emphasized individual dimensions—such as environmental, social, or economic aspects—innovability integrates these pillars into a balanced, systemic framework (De La Vega Hernández & Barcellos de Paula, 2021; Adams et al., 2016). This approach emphasizes co-creating value with diverse stakeholders, while recognizing the environment as an active stakeholder with intrinsic rights (De La Vega Hernández & Barcellos de Paula, 2021; Gilbert et al., 2023).

However, despite its conceptual potential, innovability remains underexplored, particularly in aligning innovation practices with sustainable outcomes. A scoping review in Web of Science found only 15 references explicitly addressing "innovability," with just two empirical studies examining its links to both innovation and sustainability. This limited discourse underscores the need for further research to harmonize innovation processes with sustainability and address the complex challenges of the Anthropocene (Pereira et al., 2025). Recognizing the fragmented and interdisciplinary nature of the existing research – spanning areas such as policy, ethics, and technology management (Cillo et al., 2019) – the scope of the review for this research was expanded to include combinations of related terms such as sustainable innovation, innovation for sustainability, stakeholder engagement, environmental inclusion, and biodiversity. A search using specified terms in titles, abstracts, or keywords in the Web of Science database initially yielded 307 results. The

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology (Moher et al., 2010) was then applied to identify relevant studies for inclusion, as shown in Figure 1. The search was subsequently refined to remove duplicates, non-English language documents, non-peer-reviewed articles, and studies outside the management field, as the study focuses on managerial perspectives and the integration of innovation and sustainability within organizational contexts. This refinement resulted in 93 entries for consideration.

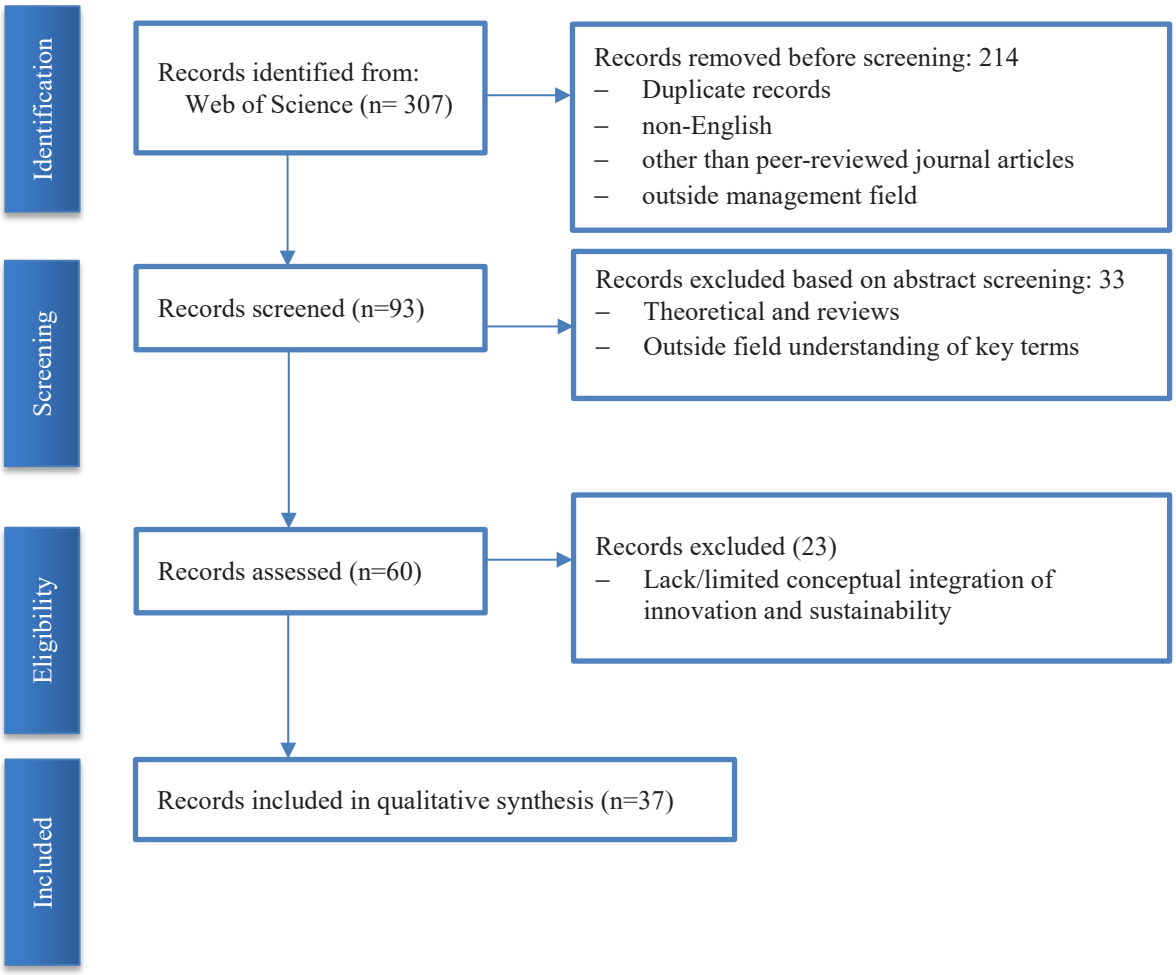


**Figure 1**. PRISMA flow diagram of performed systematic literature review

During the screening stage, 33 entries were excluded, primarily due to their theoretical or review-based nature, lacking empirical evidence. To focus on original empirical research, we excluded illustrative case studies, systematic reviews, and other non-empirical works to maintain methodological rigor and avoid redundancy. This process resulted in a final sample of 60 articles for eligibility assessment. Following this, a review of the abstracts led to the exclusion of an additional 23 articles. These either referenced sustainable innovation in overly general terms, failing to address the key challenge of innovability—the meaningful integration of innovation and sustainability—or offered only limited insight into the specific dynamics of how these concepts intersect. Others focused solely on selected aspects—economic, social, or environmental. This resulted in a final sample of 37 relevant articles for the qualitative synthesis.

The co-occurrence analysis of keywords resulted in overly distributed, multi-themed outputs with little depth at this stage, likely reflecting the early developmental state of the field. To address this, we conducted a content analysis using thematic analysis.

The thematic analysis of the literature reveals four interconnected themes that address the challenge of integrating innovation and sustainability, encapsulating the economic, social, and environmental dimensions of **innovability.** The first theme, *Stakeholder participation and collaborative practices*, underscores the significance of partnerships and co-

creation in driving sustainability-oriented innovation. Effective collaboration enables diverse stakeholders to align their goals and foster shared solutions, as partnerships bridge gaps in expertise, resources, and priorities. This theme highlights how inclusive frameworks facilitate trust and engagement, while addressing tensions that may arise due to differing organizational logics (Watson et al., 2024; Cambra-Fierro et al., 2023). For example, co-creation between businesses and communities can create shared value by integrating local needs with broader sustainability goals (Goodman et al., 2017).

The second theme, *Context specific nature of sustainability efforts*, highlights that the integration of innovation and sustainability is shaped by the unique socio-economic and ecological conditions of each context, requiring tailored approaches rather than one-size-fits-all solutions. In urban settings, public-private collaborations, such as smart urban projects, demonstrate how technological advancements can address challenges like pollution and citizen well-being by aligning with local needs (Cambra-Fierro et al., 2024). Humanitarian settings, such as refugee camps, highlight the importance of balancing environmental priorities with social needs through operational innovations that improve quality of life under resource constraints (Seifert et al., 2022). Similarly, in agriculture, the adoption of technologies like drip irrigation showcases the necessity of reconciling economic feasibility with environmental goals to meet the realities of farming communities (Greenland et al., 2019).

The third theme, *Scaling sustainable practices and innovation models*, focuses on the systemic expansion of sustainability initiatives, emphasizing the importance of innovative frameworks that enable broader adoption and impact. Scaling sustainability often involves aligning business practices with global frameworks such as the United Nations Sustainable Development Goals (SDGs), as well as utilizing tools like life cycle assessment methodologies to evaluate and enhance environmental performance (Rosati et al., 2023; Goffetti et al., 2023). Dynamic capabilities play a key role, allowing organizations to adapt to shifting societal, regulatory, and market expectations, as seen in industries such as energy and fashion, where sustainability transitions require iterative experimentation and learning (Franzè et al., 2024; Wadin & Bengtsson, 2022). Furthermore, the integration of circular business models, including product-service systems, offers a promising avenue for scaling sustainable practices by decoupling economic growth from resource consumption (Sattari et al., 2022).

Meanwhile, the final theme, *Challenges and barriers to sustainability integration*, addresses the complex obstacles that hinder the effective implementation of sustainability-oriented innovation. Regulatory constraints, conflicting stakeholder priorities, and resource limitations frequently challenge organizations striving to embed sustainability into their operations (Martielli et al., 2024). For instance, small and medium-sized enterprises (SMEs) often face financial and infrastructural barriers that limit their ability to adopt innovative practices, despite their potential for impactful sustainability contributions (Bos-Brouwers, 2010). Stakeholder conflicts further complicate integration, as differing values and objectives between partners can create tensions, particularly in cross-sector collaborations (Stål et al., 2022). Moreover, cultural resistance and lack of institutional support can impede the adoption of sustainable technologies, as illustrated by the slow uptake of water-efficient irrigation systems in agricultural contexts (Greenland et al., 2019).

The insights align with arguments that integrating innovation and sustainability is inherently shaped by the strategic use of diverse forms of knowledge, developed through structured processes and dynamic interactions (Cillo et al., 2019; Pereira et al., 2025). The reviewed literature highlights that various forms of knowledge – including structured frameworks and formalized methodologies spanning scientific research and industrial R&D, as well as context-specific practices and experiential insights from stakeholder interactions – are essential for guiding innovation toward sustainable outcomes (Alcalde-Heras & Carrillo-Carrillo, 2024; Marzucchi & Montresor, 2017; Rosati et al., 2023). These dynamics illustrate that sustainable innovation emerges from the interplay of diverse informational inputs and their application in specific contexts (Greenland et al., 2019; Goodman et al., 2017). This interplay is particularly important in addressing environmental impacts at both production and consumption levels, where solutions must integrate technological rigor with local adaptability to achieve meaningful outcomes (Alcalde-Heras & Carrillo-Carrillo, 2024).

This dynamics aligns closely with two distinct modes of innovation: Science and Technology-based Innovation (STI) and Doing, Using, and Interacting (DUI) (Jensen et al., 2007; Najda-Janoszka, 2025). The STI mode reflects the structured, systematic processes that underpin technological advancements, codified knowledge, and breakthrough innovations, primarily driven by academic, corporate, or governmental research and development (Jensen et al., 2007; Alcalde-Heras & Carrillo-Carrillo, 2024). In contrast, the DUI mode emphasizes the value of tacit knowledge and experiential learning, derived from iterative, context-specific feedback and stakeholder interactions (Marzucchi & Montresor, 2017; Parrilli & Heras, 2016). While STI fosters transformative, research-driven innovation, DUI thrives on adaptability, enabling incremental, user-centred improvements that are often critical in addressing specific local or environmental challenges

(Thomä, 2017; Goodman et al., 2017). Studies suggest that integrating STI and DUI modes can significantly enhance innovation outcomes by combining the strengths of both approaches (Beynon et al., 2024; Alhusen & Bennat, 2021). By merging formal scientific research with practical experiential learning, organizations can create innovations that are not only technologically advanced but also highly relevant to market needs and adaptable to real-world conditions (González-Pernía et al., 2015; Carrillo-Carrillo & Alcalde-Heras, 2021). This integration bridges the gap between theoretical knowledge and practical application, fostering an environment that supports continuous improvement and adaptive learning (Isaksen & Nilsson, 2013; Marzucchi & Montresor, 2017).

However, integrating STI and DUI modes is complex and highly context-dependent, shaped by regional, sectoral, and temporal factors. STI's emphasis on scientific rigor and codified knowledge contrasts with DUI's focus on tacit, experiential learning, making their integration conceptually complementary but practically challenging (Najda-Janoszka, 2025; Piercey et al., 2025). For example, peripheral regions often rely on DUI due to resource constraints and the local nature of experiential knowledge, while metropolitan regions are better positioned to leverage STI for structural innovation, benefiting from access to advanced R&D infrastructure and skilled labor (Beynon et al., 2024; Piercey et al., 2025). These disparities highlight the need for context-sensitive strategies that align with regional capabilities and innovation goals. Sectoral dynamics further amplify the challenges of STI-DUI integration. In industries where innovation speeds and time horizons differ, integrating tacit supply-chain knowledge with STI's codified research often results in misaligned objectives and coordination difficulties (Haus-Reve et al., 2019; Simms & Frishammar, 2024). For instance, high-tech and low-tech firm collaborations face challenges in bridging knowledge gaps, coordinating efforts, and aligning objectives (Simms & Frishammar, 2024). These tensions are further exacerbated as firms often struggle to balance the volume of external inputs with their capacity to process and utilize ideas effectively, resulting in inefficiencies and fragmented innovation efforts (Haus-Reve et al., 2019). Additional coordination difficulties arise when attempting to align STI's codified, structured knowledge with DUI's tacit, experience-based insights, which can lead to misaligned objectives or redundant activities (Simms & Frishammar, 2024). Partnerships can further complicate matters by causing strategic misdirection, where firms prioritize technically intriguing ideas that fail to address operational or market priorities (Beynon et al., 2024). These challenges underscore the importance of robust knowledge management systems to facilitate communication, align expectations, and establish shared frameworks for collaboration (Simms & Frishammar, 2024). Additionally, adopting an ambidextrous approach (Zakrzewska-Bielawska, 2021) can help balance STI's exploratory potential with DUI's practical adaptability, allowing firms to address immediate challenges while progressing toward long-term sustainability goals (Raisch & Birkinshaw, 2008; Cillo et al., 2019).

Despite these challenges, the integration of STI and DUI modes presents a promising framework for addressing critical sustainability issues, particularly in urban contexts. However, theoretical frameworks addressing the dynamics of STI and DUI integration remain underdeveloped, especially in relation to urban sustainability challenges, where the complementary roles of both modes could foster adaptable and rigorous innovations. This gap is particularly notable in the domain of biodiversity, which often remains an implicit rather than explicit focus in sustainability-oriented innovation efforts, even though it is critical for maintaining ecosystem services (Cambra-Fierro et al., 2024; Greenland et al., 2019). While studies frequently address related concerns such as environmental performance, urban pollution, and resource management, targeted approaches to directly address biodiversity loss and ecosystem degradation remain limited. This gap highlights the potential of STI and DUI integration to tackle the complexities of urban biodiversity management, which requires balancing ecological preservation with the pressures of urban development (Mainwaring et al., 2024). Urban biodiversity management seeks to maintain and enhance biodiversity within cities increasingly threatened by human activity, infrastructure expansion, and habitat fragmentation (Biella et al., 2025). As cities grow, these pressures intensify, creating a dynamic tension between the need for biodiverse green spaces and competing land-use demands (Kopnina et al., 2024). This challenge extends beyond environmental integrity, encompassing deeply interwoven social and economic dimensions (Mainwaring et al., 2024). Biodiversity loss undermines essential ecosystem services, such as air purification, temperature regulation, and flood control, directly impacting urban populations (Genovese et al., 2023). Therefore, finding sustainable, innovative approaches to preserve urban nature is crucial for societal well-being and the functioning of urban ecosystems (Bruno et al., 2024).

Managing urban biodiversity effectively, however, is inherently complex and requires a context-specific approach that addresses the diverse social, economic, and environmental challenges cities face. Urban biodiversity initiatives must navigate the varied interests of stakeholders, including government agencies, private entities, NGOs, local communities, and environmental organizations, each of which brings distinct priorities and levels of engagement (Biella et al., 2025; Kopnina

et al., 2024). A key challenge lies in reconciling ecological preservation with aesthetic and functional needs, as exemplified by lawn mowing practices (Sehrt et al., 2020). Frequent mowing, motivated by concerns such as aesthetics, administrative costs, and tick prevention, limits biodiversity by favoring a narrow range of species (Ignatieva & Hedblom, 2018; Watson et al., 2020). Conversely, less frequent mowing, or a "low-intensity regime," fosters greater plant diversity, supports small organisms, reduces overheating, and mitigates the urban heat island effect (Biella et al., 2025; Watson et al., 2020). Despite evidence that reducing mowing frequency enhances biodiversity and reduces administrative costs (Watson et al., 2020), its large-scale adoption remains constrained by gaps in understanding how to implement these practices effectively, public perceptions, and integration into urban planning frameworks. Bridging scientific rigor with practical, stakeholder-driven approaches appears crucial for overcoming these barriers. Integrating structured STI knowledge with DUI methods may enable practical, adaptable strategies, fostering sustainable urban biodiversity solutions.

Integrating STI and DUI modes and fostering innovability requires frameworks that enable their convergence in practical settings. **Living Labs** provide a collaborative platform for integrating structured research (STI) with experiential learning (DUI) to address sustainability challenges. Drawing on theories of open innovation, participatory design, and systems thinking, Living Labs engage researchers, businesses, public authorities, and communities in co-creating, testing, and refining solutions (Schuurman et al., 2016; Nyborg et al., 2023). By merging ecological, technological, and social insights through participatory methods such as workshops and iterative feedback, they bridge theoretical knowledge with practical application, fostering interdisciplinarity and transdisciplinarity (Fam et al., 2020).

Building on this concept, **Campus Living Labs** transform universities into innovation hubs, engaging students, faculty, and stakeholders to tackle real-world issues such as biodiversity loss and sustainable urban development (Evans et al., 2015; Fam et al., 2020). These labs integrate STI's structured research methods, such as experiments and data analysis, with DUI's adaptive, stakeholder-driven practices to ensure solutions are scientifically robust and socially relevant (Nyborg et al., 2024; McCrory et al., 2022). Inter- and transdisciplinary collaboration is central to this process, drawing on natural sciences for ecological insights, engineering for technological solutions, and social sciences for stakeholder engagement and societal dynamics. Participatory methods align these contributions toward shared goals, while embedding problem-solving into education helps participants develop technical skills, systems thinking, and collaborative capabilities (Nyborg et al., 2024; Verhoef et al., 2019). By integrating systems thinking and participatory methodologies, Campus Living Labs exemplify the potential for interdisciplinary collaboration and scalable solutions to complex sustainability challenges (Nyborg et al., 2024; Fam et al., 2020). However, despite their promise, empirical studies documenting how STI and DUI modes interact within these frameworks remain scarce, highlighting a need to explore how participatory processes shape sustainable innovation outcomes

In summary, integrating STI and DUI modes through frameworks like Living Labs – particularly Campus Living Labs – presents a promising opportunity to address the complexities of urban biodiversity and sustainability challenges. While promising, this approach raises critical questions for further exploration: (1) How can this integration facilitate innovability in urban biodiversity projects? (2) What tensions and challenges arise, and how can they be addressed? (3) How does stakeholder engagement influence innovation and institutionalization of sustainable practices? These questions aim to uncover strategies for optimizing STI-DUI integration, addressing tensions, and enhancing stakeholder engagement to institutionalize sustainable practices.

## METHODOLOGY

### Research design (contextualization)

This study employs a single case study design to explore the integration of STI (Science, Technology, and Innovation) and DUI (Doing, Using, and Interacting) modes within the "To Mow or Not to Mow?" project at Jagiellonian University. Single case studies are particularly suited for investigating complex, contemporary phenomena in their real-world contexts, where detailed, contextual understanding is essential (Yin, 2017; Flyvbjerg, 2006). This approach facilitates an in-depth examination of the specific dynamics between STI and DUI, capturing nuanced insights that broader research designs often overlook (Ridder, 2017). The "To Mow or Not to Mow?" project, with its dual focus on biodiversity and sustainability, serves as a bounded unit of analysis, providing a rich context for studying how structured scientific methods intersect with participatory, user-driven processes.

The selection of this project as the unit of analysis is deliberate (Yin, 2017), reflecting its relevance to urban biodiversity challenges such as habitat degradation, species loss, and climate adaptation. A systematic review conducted as part of this research revealed a significant gap in empirical studies addressing urban biodiversity issues, particularly urban lawn management, from a perspective that incorporates stakeholder participation and input. The project addresses this gap directly by offering a unique opportunity to explore how formal, research-based knowledge (STI) interacts with stakeholder-driven, experiential knowledge (DUI) to co-create adaptive and socially responsive solutions. Furthermore, its reliance on the Living Lab methodology, emphasizing iterative feedback and stakeholder engagement, provides a valuable lens for examining the integration of diverse knowledge systems to address environmental challenges effectively. Finally, an ongoing study was chosen over a retrospective analysis to capture the project's real-time evolution, enabling a deeper understanding of how iterative feedback, stakeholder engagement, and adaptive decision-making unfold in practice.

Although single case studies are sometimes critiqued for limited generalizability, their strength lies in offering granular insights that inform broader theoretical frameworks (Yin, 2017; Takahashi & Araujo, 2019). To address this limitation, this study employs analytic generalization, ensuring that findings contribute to understanding STI-DUI integration across similar sustainability initiatives (Flyvbjerg, 2006). The exploratory approach prioritizes uncovering patterns, mechanisms, and challenges, particularly in contexts where existing theory offers limited guidance (Takahashi & Araujo, 2019; Ridder, 2017; Najda-Janoszka & Daba-Buzoianu, 2018). Methodological triangulation further strengthens validity by enabling cross-verification and capturing diverse perspectives (Yin, 2017). Additionally, the participatory nature of the project, involving stakeholders such as public authorities, NGOs, private residents, and businesses, enhances the findings' applicability to broader contexts.

By situating this study within a bounded, context-rich environment, the research provides both theoretical advancements and practical contributions. While it offers insights specific to urban lawn management, its findings extend to broader discussions on integrating STI and DUI modes in urban sustainability projects. This study establishes a replicable framework for similar initiatives, offering transferable lessons for fostering co-created, sustainability-oriented innovations in diverse settings.

## Data collection

Triangulation is employed in the case study research to ensure the validity and reliability of findings, utilizing multiple methods to gather comprehensive data (Najda-Janoszka & Daba-Buzoianu, 2018). These methods include interviews (using focus and semi-structured individual techniques), desk research (using structured file review and document retrieval from internal sources) and journaling (using a technique of open-ended reflective journaling) (Table 1).

To capture diverse perspectives, between January and June 2024, five focus group interviews were conducted with stakeholder groups and project participants. These sessions provided collective insights into the challenges of integration and the practicalities of project implementation. Subsequently, in July and August 2024, two semi-structured individual interviews were conducted with faculty authorities and the principal investigator of the pilot project. These interviews aimed to gather in-depth, personal reflections on the project's conditions, experiences, and outcomes. To minimize retrospective bias and provide a more dynamic understanding of the project's development, the journaling method was applied (Olorunfemi, 2024). The principal investigator of the analyzed project maintained a project diary between January and July 2024, documenting the project's progress alongside personal reflections and observations. These qualitative insights were further enriched with data from project documentation spanning September 2023 to June 2024. This documentation, systematically collected as the project was prepared and executed, provided a broader organizational context and a detailed timeline of the project's development, complementing the perceptions and observations gathered through other methods.

**Table 1.** Gathered material

| Method | Technique | Instrument | Description | Number of documents/ interviews | Number of transcribed, written pages |
|---|---|---|---|---|---|
| Interview | Semi-structured focus group interview | Scenario-based guide | Public sector (F1) – 12 participants, NGO (F2) – 10 participants, residents (F3) – 7 participants, private sector (F4) – 3 participants, pilot project principal and co-investigators (F5) – 11 participants<br>Duration: 51min – 121min<br>Timeframe: January – June 2024 | 5 | 185 |
| Interview | Semi-structured individual interview | Scenario-based guide | Pilot project principal investigator (I1), faculty authority (I2)<br>Duration: 31min – 70min<br>Timeframe: July, August 2024 | 2 | 45 |
| Desk research | Structured file review and document retrieval from internal sources | Document review protocol and catalogue | Project Proposal (PP), Project Timeline (PT), CLL Competition Rules (CLL), Protocols from Living Lab competition committee (PCLL), Flagship Project: 2023 Report (Rep1), Flagship Project: Report for the first half of 2024 (Rep2)<br>Timeframe: September 2023 – July 2024 | 8 | 76 |
| Journaling | Open-ended reflective journaling | Project diary | Pilot Project Manager's Log (PPML)<br>Timeframe: January – July 2024 | 1 | 8 |

## Data analysis

The **method** of qualitative content analysis was employed to provide a comprehensive understanding of the STI and DUI integration process. This method uses a systematic **approach** to extract rich, detailed insights from narrative data, capturing nuanced perspectives and experiences related to integration challenges, project implementation, and organizational conditions (Schreier, 2012). Within this method, the **technique** of thematic coding and categorization was applied to organize and analyze the data systematically.

The data – comprising transcripts of interviews, project documentation, and the project diary – was initially processed using NVivo software. This tool was employed for its advanced capabilities in managing large datasets and efficiently organizing coding frameworks (Paulus et al., 2014). NVivo facilitated the development of the initial coding structure, enabling the identification of key themes. However, the process was further thoroughly refined manually, allowing for a more nuanced interpretation and cross-validation of the results. This iterative combination of software-supported and traditional manual coding ensured a comprehensive and reliable analysis (Najda-Janoszka & Daba-Buzoianu, 2018; Maher et al., 2018).

The thematic coding and categorization procedure was applied across three levels of analysis: individual perspective, project implementation level, and organizational conditions. This combined approach ensures a comprehensive understanding of the integration process, from identifying challenges and evaluating strategies to examining institutional influences on project success. In our analysis, we applied theory-driven codes derived from innovation management literature on STI and DUI, and emerging codes that were inductively developed from the data where new patterns and themes emerged during the coding process**.** A systematic, iterative consensus process was undertaken by three researchers to ensure reliability. To comprehensively analyse themes and gain a deeper understanding of the various facets of STI and DUI integration, it was crucial to divide them into distinct sub-themes. The following table presents an organized overview of these sub-themes, detailing key categories, corresponding codes, and illustrative sample quotes that highlight their relevance (Table 2).

**Table 2.** Coding procedure

| **Theory driven codes** | | | |
|---|---|---|---|
| **Main category** | **Codes** | **Source** | **Sample quotes** |
| STI | Research and Development (R&D); research; scientific methods; technological advancements; formal knowledge; technical expertise; patents; lab experiments; evidence-based; data-driven | Jensen et al. (2007); Nunes & Lopes (2015); Beynon et al. (2024); Alhusen & Bennat (2021); Isaksen & Karlsen, (2010) | However, the university does have authority. And the knowledge that comes from scientific research is strong. People do follow it, after all (...) (F3_P3) |
| DUI | Practical application; experiential learning; user feedback; collaboration; hands-on; iterative process; community involvement; stakeholder interaction; fieldwork; problem-solving | Jensen et al. (2007); Nunes & Lopes (2015); Beynon et al. (2024); Alhusen & Bennat (2021); Isaksen & Karlsen, (2010) | Yes, this experience accumulates year by year, each year teaches us something... and we also make decision-making mistakes, but we learn from them and try to correct them moving forward (F1_P4). |
| **Emerging codes** | | | |
| **Main theme** | **Second order codes** | **First order codes** | **Sample quotes** |
| Integration Process of DUI and STI Modes<br>*How STI and DUI modes come together through collaboration and co-creation, while navigating the challenges of their integration within sustainability projects* | Collaborative Synergy | Combining scientific research with practical, user-centred insights<br>Combining interdisciplinary insights to address sustainability challenges<br>Living lab methodology | Well, it certainly leads to the exchange of experiences and potential cooperation, not only from the perspective of our project but also regarding other issues in general (…) (I1) |
| | Innovation Tensions | Balancing scientific rigor with practical, user-driven needs<br>Managing cross-disciplinary and cross-sectoral priorities | The humanities part has no problem with this, (...) so it's kind of their natural environment, whereas the 'exact sciences' have a big problem with it; they don't understand it at all (...) (I1) |
| Sustainability-Driven Innovation (Innovability)<br>*How integrated innovation modes produce tangible outcomes in sustainability, including environmental, technological, and social impacts* | Environmental and social responsibility | Addressing biodiversity and climate challenges through innovation<br>Engaging local communities in sustainability efforts | It was also an exchange of experiences so that we could get feedback from these people afterward—whether it worked, whether it was successful, what observations they had—whether it worked at all or didn't, or whether it required modifications. Whether it works in all conditions, and so on and so forth, to get them a bit more involved in the topic, to shift their attention away from commercial things (I1) |
| | Technological and Social Solutions | Developing user-centred, practical tools (e.g., web applications)<br>Living lab methodology | In my research, I've always aimed and strived to create utilitarian tools that can be used by society, rather than doing research just for the sake of research. The goal is to create tools for protection, tools for action, for building a better reality. So, this methodology or strategy is a perfect fit, a bullseye, in that regard. (I1) |
| Stakeholder engagement<br>*How stakeholders shape innovation through their involvement, collaboration, and the challenges of integrating diverse actors into the process* | Stakeholder roles | Contribution of public institutions, NGOs, and local communities<br>Sharing responsibility and decision-making in co-creation processes | But there are also different expectations from the residents, as the gentleman here mentioned, and even within a single building, there are already expectations. On a city-wide scale, everyone has their own opinion about mowing; we all consider ourselves experts on the subject. So, in addition to the dilemma of whether to mow or not, we also face the challenge of how to explain that the fact we are mowing is actually a good thing. (F1_P4) |
| | Collaboration dynamics | Building trust and fostering open communication among stakeholders<br>Ensuring long-term stakeholder commitment and engagement | It will be difficult to really maintain the interest of these people, or simply to keep this target engaged, so that they get involved in these activities, are interested, and truly want to educate themselves (I1) |

| Emerging codes | | | |
|---|---|---|---|
| **Main theme** | **Second order codes** | **First order codes** | **Sample quotes** |
| Project management dynamics<br>*How organizational aspects facilitate the effective integration of DUI and STI modes by ensuring coordination, support, and the resolution of practical barriers* | Project coordination | Aligning interdisciplinary teams and incorporating stakeholder input<br>Adapting project timelines to accommodate real-world constraints<br>Managing evolving stakeholder expectations and project needs | The extreme unpredictability of the weather is going to drive me crazy. This year, I can't plan anything. It was supposed to be dry – the sky is overcast and it's windy like before a storm, and then a moment later, there's unbearable heat...(…) And finally, there are some positive effects and more butterflies (PPML) |
| | Institutional support and challenges | Administrative and financial support for interdisciplinary projects<br>Managing time, resource and administrative barriers | I am glad that we have real support; we wouldn't be able to manage without it. I am worried that the procedures might drag on for a long time. What we need most of all is a detailed specification, which we can't create without focus group research. I feel immense pressure and how little time there is for everything (PPML) |
| Social impact and knowledge transfer<br>*How the project's outcomes translate into broader societal impact through public education, knowledge-sharing, and the institutionalization of practices for long-term sustainability* | Public education and outreach | Raising public awareness on biodiversity, climate issues and sustainability practices<br>Translating scientific findings into actionable knowledge for non-experts | (…) I don't believe that we will be able to do something like that, that we will... suddenly stop mowing lawns, right? And I think we need to find some kind of compromise here (…) (F2_P2) |
| | Institutionalising innovation | Creating frameworks for continuous collaboration (beyond the project's duration)<br>Establishing long-term knowledge-sharing mechanisms | I would like to strengthen this (...) there will be an appointee responsible for external collaboration. We are supposed to establish a council for cooperation. We are going to invite a few people to join. We will try to get certain things moving, and that will be her task, to get this cooperation going. (…) And I think these will also be projects that will have a more implementation-oriented character. Meaning, the University wants to open up to various collaborations and institutionalize this somehow. But if I had to tell you in three straightforward words how I see it? Right now, I'm at the stage where the more projects that bring benefits to researchers and students, the better, simply put (I2) |

## Validity and reliability

To ensure the rigor and trustworthiness of the study, multiple validation strategies were applied, aligning with qualitative research standards (Lincoln & Guba, 1985; Najda-Janoszka, 2016). Credibility was enhanced through methodological triangulation. The use of multiple methods, techniques and data sources allowed for cross-verification of findings, reducing the risk of bias and increasing the robustness of interpretations. Dependability was ensured through researcher triangulation, with three researchers independently conducting coding and validating emerging themes. NVivo software facilitated initial coding, while manual verification provided deeper contextual interpretation, improving analytical rigor. Confirmability was addressed by implementing a transparent and systematic data analysis process. To mitigate potential researcher bias—particularly given the involvement of the principal investigator (PI) as a co-author—two additional researchers, not directly affiliated with the PI, independently reviewed and validated the findings. The study adhered to a structured protocol for data collection, coding, and thematic development, ensuring that interpretations were grounded in the data rather than researcher preconceptions. Finally, analytic generalization (Yin, 2017) strengthened transferability, ensuring that insights from this case study contribute to broader discussions on STI-DUI integration in sustainability projects. By providing detailed contextual analysis and a replicable framework, the study offers findings relevant beyond its immediate case. These measures enhance the validity and reliability of the research, reinforcing its contribution to innovation and sustainability studies.

# FINDINGS

The findings begin with a detailed presentation of the *To Mow or Not to Mow?* project, establishing it as the unit of analysis and situating it within Jagiellonian University's Campus Living Lab. This section outlines the project's objectives, methodology, and the specific challenges it addresses, particularly in sustainable urban lawn management. Following this overview, the analysis builds on themes identified through the coding and categorization process (Table 2), examining the integration of DUI and STI knowledge modes, stakeholder engagement dynamics, and the project's broader social impact.

## The outline of the case chosen – "To Mow or Not to Mow?" project

The "To Mow or Not to Mow?" project, launched in 2023 as part of Jagiellonian University's Campus Living Lab (CaLiLab), seeks to promote sustainable urban biodiversity management by exploring how different lawn mowing frequencies impact ecosystems. As urbanization intensifies, creating urban heat islands and reducing biodiversity (Mainwaring et al., 2024), traditional landscaping practices such as frequent mowing are becoming increasingly unsustainable. This project challenges those practices and aims to identify biodiversity-friendly alternatives for urban green space management (Biella et al., 2025; Watson et al., 2020). The urgency of such initiatives is underscored by global biodiversity crises, with evidence suggesting we are already experiencing the sixth mass extinction driven by human activities (Barnosky et al., 2011; Tollefson, 2019).

Frequent mowing is often valued for its aesthetic appeal but restricts plant species from flowering, limiting biodiversity (Biella et al., 2025). Additionally, intensively mowed lawns are less resilient to heat and drought, often leading to dead patches that require frequent watering, fertilization, and herbicide application. These interventions generate noise, dust, and greenhouse gases, contributing to further environmental degradation (Watson et al., 2020). Recent research demonstrates that reducing mowing frequency can increase plant species diversity by up to 30%, thereby providing more food sources and shelter for pollinators, which are essential for healthier urban ecosystems (Sehrt et al., 2020).

The "To Mow or Not to Mow?" project's primary goal is to develop scientifically backed recommendations on lawn management practices that optimize biodiversity while meeting the aesthetic and functional needs of urban residents. Another major objective is the development of a web-based application to guide users in making informed decisions about sustainable lawn care (PP). This application will integrate scientific data and stakeholder feedback to create a practical tool that balances environmental benefits with everyday lawn management needs. The experimental phase of the project includes 64 plots with varying mowing frequencies, ranging from one to eight cuts per year, as well as plots mowed only once every two years (PP). Over the course of three growing seasons, the study assesses a range of environmental parameters, including microhabitat conditions, soil fauna activity, soil bacterial and fungal diversity, soil respiration rates, above-ground biodiversity, mycorrhizal development, tick exposure, and the risk of invasive species encroachment (PP). This comprehensive analysis will provide key insights into how different mowing practices affect urban ecosystems.

A critical feature of the "To Mow or Not to Mow?" project is its participatory approach, facilitated by CaLiLab. Launched in spring 2023 at Jagiellonian University, this innovation platform supports collaborative research and the co-creation of solutions through funding, training, and mentoring (CLL). By engaging a diverse range of stakeholders—including academia, businesses, public authorities, and community members—CaLiLab fosters the development of practical, real-world solutions to environmental challenges. Within the Living Lab framework, the Jagiellonian University campus serves as a microcosm of wider society, providing a controlled environment for experimenting with and refining innovative ideas (Stuckrath et al., 2025; Martek et al., 2022). The CaLiLab approach to participatory research follows a quintuple helix model, incorporating the natural environment as a legitimate stakeholder, which further enriches the co-creation process (Rep. 1; Rep. 2). Interdisciplinary and participatory approaches are not only encouraged but also supported and expected in funded projects (PCLL). Depending on the project's initial design, these aspects can be expanded and deepened during execution, with merit-based support provided by CaLiLab (PCLL).

The "To Mow or Not to Mow?" project has been structured into several phases in alignment with the CaLiLab approach (PP; PT). The initial test phase in 2023 involved pilot studies on the Jagiellonian University campus to assess the basic impacts of mowing frequency on biodiversity. This phase can be characterized as scientific experimentation within the framework of formal knowledge creation through structured research (STI). Based on the results obtained, the full project was developed and, in December 2023, was selected for formal financial support from CaLiLab. Since then, the project has benefited from ongoing training, mentoring, and substantive guidance provided by the platform. The expanded version of the project broadened its research scope to include inter and transdisciplinary collaboration with deeper stakeholder engagement. The scientific team was extended to include geographers, social communication experts, and management scientists, while stakeholder participation increased with the involvement of public sector officials, non-governmental organizations, private garden owners, and business representatives. As a result, the STI approach was combined with multi-stakeholder engagement, iterative feedback, and tacit knowledge transfer—key characteristics of the DUI mode. In 2024, the actual participatory activities were implemented, marking the integration process of the two innovation modes. By the end of 2025, the project aims to produce comprehensive recommendations on optimal mowing practices and launch a web application that will provide data-driven guidance for sustainable lawn management. Ongoing

collaboration with stakeholders and the incorporation of their input will shape both the project's recommendations and the design of the web-based application, ensuring it meets the diverse needs of urban stakeholders.

The current study focuses on this second phase (December 2023 – August 2024), specifically examining the process of integrating the two innovation modes.

## Thematic analysis of key findings

The analysis unfolds in three key areas, guided by the themes identified through the coding and categorization process and aligned with the study's three research questions (Table 2). First, it examines the integration of DUI and STI knowledge modes, exploring their synergy, tensions, and how they shape the project within the broader concept of innovability. Next, it investigates stakeholder engagement, focusing on participant roles, shared responsibilities, and project management dynamics. Finally, the analysis turns to the project's social impact, highlighting its role in public education on biodiversity and climate issues while outlining frameworks for fostering ongoing collaboration.

## Integrating STI and DUI for innovability – synergies and tensions

The data gathered across focus and individual interviews, project documentation, project diary, reveals that both STI and DUI modes are simultaneously present and actively used in the 'To Mow or Not to Mow?' project. The STI mode is evident in the project's reliance on formal research methods and scientific inquiry (PP), as it conducts '*complex, multi-area experimental research*' that is '*unique due to the large number of factors studied and the broad, diverse area covered.*' (I1) This reflects a structured, data-driven approach to innovation, characteristic of the STI mode. On the other hand, the DUI mode emerges through the active involvement of external stakeholders in the innovation process (PP). The project invites people from outside academia to contribute their perspectives, a practice rarely seen in traditional science: '*We invite people from outside to give their input, we listen to their voices... and we consider their feedback in creating our recommendations.*' (I1).

The documentation confirms that the project design is clearly based on the integration of STI and DUI modes (PP; PCLL). Its goal is not only to conduct in-depth research but also to develop user-centered tools, including a web application, through a participatory research process. These tools serve as part of the project's technological and social solutions to standardize sustainable mowing practices (PP). Protocols from the CaLiLab competition committee (PCLL) indicate compliance with the Living Lab's participatory approach by combining scientific rigor with community engagement, ensuring that solutions are shaped by both data and stakeholder experiences. Importantly, an interview with faculty authorities signals institutional commitment to supporting this research direction, with explicit interest in expanding opportunities for academic engagement and enhancing researchers' competencies: *"[It] facilitates a different way of employee activity" and allows researchers to "go outside" and test ideas before scaling them up"* (I2). This perspective extends beyond merely combining disciplinary expertise within research teams toward a **transdisciplinary approach**, where disciplines merge beyond their boundaries and integrate non-academic (societal) knowledge from practitioners, policymakers, and communities.

The integration of STI and DUI modes in the project fosters transdisciplinary synergy by bringing together biologists (including botanists, zoologists, and environmentalists), geographers, communication experts, and management scientists. Rather than simply combining distinct disciplinary perspectives, methods, and knowledge, the project design assumed a merging of expertise, with researchers working closely together toward a common, real-world solution that is both scientifically rigorous and practically applicable (PP). The selection of project team members was based on their ability to contribute their specialized expertise while also engaging in deep collaboration across disciplines (I1). While the biology and geography teams led the experimental research, they acknowledged the need for expertise in stakeholder communication and engagement, which led to the inclusion of social science researchers. Their role was not limited to supporting outreach efforts but was integral to the project's co-creation process, ensuring that scientific findings translated effectively into actionable, stakeholder-driven solutions (I1). Similarly, cross-sectoral synergy was recognized as crucial for the project's success, with input from various stakeholders, including public sector representatives, NGOs, and the local community, ensuring that the developed solutions are both ecologically sustainable and socially accepted:

> *'It would be very useful now if the city commissioned such monitoring studies every year to assess our chances of getting infected by ticks, to show that not every tick is dangerous' (F2_P3)*

While the project was designed to integrate diverse expertise through a transdisciplinary approach, its execution revealed tensions and challenges in practice, as documented in interviews and the project journal (PPML). Aligning and managing the diverse contributions within the project proved difficult, particularly due to ontological and epistemological differences between disciplines. As noted, *'the humanities have no problem with this, (...) it's their natural environment, whereas the exact sciences struggle with it; they don't understand it at all'* (I1). These challenges were further compounded by the differing perspectives and practices among stakeholders from various sectors. For example, allotment garden owners often form a tight-knit community with a clear understanding of gardening, emphasizing control over nature through frequent mowing and the removal of unwanted plants and animals. This perception extends to garden managers and housing cooperatives, who also struggle to grasp the importance of biodiversity and the benefits of less intensive lawn care. Some participants expressed anthropocentric views, driven by fear and personal priorities, seeing biodiversity as a threat:

> *'But there are also different expectations from residents, as you mentioned, and even at the level of a single block, there are already expectations. On the scale of the whole city, everyone has their own opinion about mowing; we all think we know about it' (F1_P4)*

Tensions also emerge in balancing scientific objectives with stakeholder expectations. Scientists find it difficult to accept non-scientific arguments, which intensifies the conflict and generates internal resistance. Disagreements arise between the goals of biologists and the practical needs of stakeholders. While there is hope for a tool to unify these practices, scepticism remains: *'The question is, will there be any willingness to use something like this?'* (F4_P2). This highlights the challenge of reaching a compromise that respects both scientific recommendations and public input, underscoring the need for ongoing dialogue throughout the project to ensure flexible and adaptive approaches. The Living Lab methodology provides a suitable framework and toolbox to facilitate this process, yet its effectiveness is constrained by the fact that CaLiLab itself is still in an emergent phase. As a developing initiative, it is still refining its mechanisms for long-term stakeholder engagement, structured collaboration, and interdisciplinary integration (Rep1; Rep2).

## Stakeholder engagement and project dynamics

Stakeholder engagement in the "To Mow or Not to Mow?" project is a dynamic and evolving process aimed at addressing the challenges of integrating STI and DUI modes. The strategy focuses on continually involving new stakeholders, expanding the network, and articulating emerging expectations. Key moments of collaboration – touchpoints – were identified, where stakeholders from different sectors were brought together to address specific problems and achieve project milestones. Participation took various forms, ranging from focus interviews and the construction of ecological installations on campus to nature walks that encouraged more open and interactive exchanges (Rep.1; Rep.2). These touchpoints are critical as they act as enabling constraints, with new insights often bringing new tensions:

> *'It was about connecting different disciplines... And then it turned out that A[…] saw an area of contact, although for me it was initially completely unclear' (I2).*

Engagement is managed through negotiation and mediation, aiming to make stakeholders feel they are organically contributing to the project's direction: "*I don't want to impose anything. I would prefer that people are convinced they came up with it themselves*' (I1). It helps in building trust and fostering open communication among diverse stakeholders, which is essential for overcoming tensions and aligning goals. Despite this inclusive approach, the temporary nature of the project presents a barrier to sustained engagement, with some stakeholders expressing concern over whether the collaboration will continue beyond the project's duration: '*The downside is that... when the grant or project ends, the forum ends too. There's no guarantee it will survive*' (F3_P6). This highlights the need for longer-term strategies to maintain stakeholder involvement and ensure the project's sustainability.

The management of the project required a high level of coordination and flexibility. The first eight months were particularly intense, with activities ranging from field experiments to engaging with the socio-economic environment. A key challenge in project management was dealing with the unpredictability of weather, which necessitated frequent adjustments to the project's detailed schedule. This unpredictability had a significant impact on the organization of the project team and the well-being of its members, '*the enormous unpredictability of the weather wears me down nervously*' (PPML).

Executing the project in line with the living lab methodology added another layer of complexity. Researchers were required to step out of their traditional roles and engage with stakeholders, necessitating the development of new skills and competencies. This transition was challenging for many team members who were accustomed to strictly scientific tasks:

> *'it is extremely difficult because here we have many strictly scientific tasks and many soft ones. So, for me, it's something completely new, as it combines two types of projects' (I1).*

The 24-month timeframe allotted for the project's completion further intensified these challenges, as the team had to balance experimental research, stakeholder engagement, and the development of web applications, all while managing communication and promotional activities – '*the deadlines are very demotivating... we don't have enough time*' (I1).

Institutional support was crucial in advancing the project. The interdisciplinary team, comprising nearly twenty researchers, Ph.D. students, and students from various fields, was brought together through extensive academic experience and networking. However, the project faced challenges such as complex administrative procedures and inadequate compensation for staff, which impeded full engagement. Despite these obstacles, CaLiLab succeeded in fostering a collaborative, trust-based ecosystem—'*The path seems much more pleasant... Thanks to the people who work here and are genuinely friendly, creating an amazing atmosphere of good work*' (I1). This support included access to CaLiLab's network, expert guidance, and an expanding array of training resources (PPML). Nevertheless, CaLiLab, as an emerging entity, faces challenges in developing tools for effective stakeholder engagement and building long-term relationships (Rep.1; Rep.2). A significant limitation within the quintuple helix model is the structure of innovation projects themselves, often seen outside the university as rigid, short-term, and goal-oriented. This perception can hinder long-term collaboration and trust with external stakeholders.

## Social impact and institutionalization of practices

The "To Mow or Not to Mow?" project has made a significant social impact by engaging in public education and outreach to raise awareness about biodiversity, climate change, and sustainable practices. The research highlights the deeply rooted "lawn-mowing culture," where frequent mowing is not just a routine but an expression of control and personal aesthetics. One participant remarked, '*I don't believe we'll be able to suddenly stop mowing lawns. I think we need to find a compromise here*' (F2_P2). The project goes beyond merely informing the public, it actively seeks to transform ingrained social attitudes through hands-on engagement, such as wildflower meadow planting workshops (Rep. 2). Through public outreach, it also challenges the long-standing norm of frequent mowing, which many view as a symbol of control over nature, *'Mowing is more than a habit; it's part of a culture where controlling nature is viewed as necessary'* (F2_P2). It achieves this through direct interaction, such as hands-on activities like wildflower meadow planting workshops (Rep. 2). By addressing habitual behaviors, the project responds to global climate challenges while enhancing the university's reputation as a leader in social innovation. This recognition has placed additional pressure on the project team to deliver impactful outcomes, as one member noted: '*Our pilot project suddenly became a flagship project for the department in the context of mitigation of climate change and biodiversity loss... which is flattering, but it also brings a burden*' (I1).

Institutionalizing innovation is a core objective of the project, which employs the Living Lab methodology to create frameworks for ongoing collaboration and long-term knowledge-sharing. It serves as a model for integrating academic research with practical community engagement, involving a broad spectrum of stakeholders – from the public to socio-economic entities – to develop practical tools and strategies for real-world challenges. Stakeholder involvement has been critical at every stage, from research to the co-creation of a web-based application. This co-creation process, as one participant highlighted, is innovative because '*we invite outsiders to give their feedback, which we then use to develop our recommendations. This rarely happens in science*' (I1).

Importantly, the project's impact has been reinforced by strong institutional support. The Living Lab approach has received pronounced commitment not only from the Faculty but also from the central authorities of the university, demonstrating a broader institutional investment in participatory, transdisciplinary research (I2; Rep.1; Rep.2). This support enhances the potential for scaling such initiatives beyond a single project, embedding them into the university's long-term research and engagement strategies. The project's social impact extends beyond its immediate environmental goals, further establishing the university as a leader in social innovation. By facilitating public dialogue on biodiversity and engaging diverse community members, the initiative has sparked broader conversations about the role of urban spaces in addressing global climate challenges. This heightened visibility has placed added pressure on the project team to

deliver long-term, meaningful outcomes. However, it has also emphasized the need to continue fostering innovation and collaboration even after the project concludes.

Despite challenges – such as the project's temporary nature and the difficulty of maintaining stakeholder engagement over time– it represents a crucial step toward embedding participatory, science-based practices in urban biodiversity management. By fostering a sense of shared responsibility and collaboration, the project has laid the groundwork for long-term institutionalization. The development of a web-based application further ensures that these efforts remain accessible and actionable, helping users make informed decisions about lawn care while balancing ecological and socio-economic considerations. Through these initiatives, *To Mow or Not to Mow?* not only bridges the gap between academic research and community-driven action but also contributes to lasting cultural and institutional change in sustainable urban green space management.

## DISCUSSION

The "To Mow or Not to Mow?" project exemplifies a balanced integration of STI (Science, Technology, and Innovation) and DUI (Doing, Using, and Interacting) modes for biodiversity and climate challenges. However, the broader academic landscape still lacks sufficient research that systematically embeds stakeholder participation in biodiversity innovation (Biella et al., 2025; Boiral & Heras-Saizarbitoria, 2017). Most biodiversity studies continue to emphasize scientific advancements without fully integrating social dimensions or stakeholder engagement (Biella et al., 2025). This gap is problematic, as sustainability transitions require not only technical solutions but also inclusive, participatory approaches that ensure long-term viability and acceptance of conservation measures (Boiral & Heras-Saizarbitoria, 2017).

Although STI-based approaches provide essential technical and scientific foundations, they frequently operate in isolation from the social realities and knowledge systems of local communities, policymakers, and practitioners. The neglect of co-creative, DUI-based methodologies results in rigid solutions that may lack adaptability to diverse ecological and socio-economic contexts (Lécuyer et al., 2024). Research institutions often prioritize expert-driven models (Jensen et al., 2007), side-lining experiential learning, and interactive innovation that could enhance the relevance and uptake of biodiversity strategies. Moreover, although co-creation in innovation has been widely discussed in business and technological fields (Ramaswamy & Gouillart, 2010; Najda-Janoszka & Sawczuk, 2022), its application to biodiversity remains underexplored. There are few empirical studies on how stakeholder participation directly influences biodiversity innovation beyond consultative roles (Lécuyer et al., 2024). Theoretical frameworks acknowledge the importance of integrating local knowledge (Stuckrath et al., 2025), but practical implementations remain sparse, particularly in higher education and research-driven sustainability projects.

Theoretically, combining STI's formal research with DUI's experiential learning can enhance innovation outcomes by merging structured knowledge creation with practical adaptability (Jensen et al., 2007; Najda-Janoszka, 2024). However, the project's findings revealed significant tensions that arise and multiply during the integration of these modes throughout project implementation. This supports existing research that highlights the challenges of integration, indicating that efforts to combine STI and DUI often lead to conflicts and inefficiencies (Haus-Reve et al., 2019; Alcalde-Heras & Carrillo-Carrillo, 2024; Marzucchi & Montresor, 2017). These challenges are especially evident in university settings, where formal research and operational practices often exist in silos, within single disciplines. This limited interdisciplinary collaboration bounds the potential for transdisciplinary solutions needed for complex, real-world problems (Fam et al., 2020; Stuckrath et al., 2025). Research in academia is usually guided by rigid disciplinary norms, prioritizing depth over breadth, which can hinder the integration of diverse knowledge bases (Fam et al., 2020; Perkmann & Walsh, 2009). In the investigated project, tensions at the ontological and epistemological levels emerged right from the start. There were significant differences in how participating academics from different disciplines understood key constructs such as "experiment," "lab," or "engagement" (F5). As the project progressed, differing perspectives on research priorities became apparent, leading to ongoing discussions about the direction and focus of subsequent tasks. These discussions intensified as various outcomes were expected, highlighting the challenge of aligning diverse academic viewpoints within a single project framework (PPML, I1).

Furthermore, the divide between research and practical application reinforces the siloed approach commonly observed at universities (Perkmann & Walsh, 2009; Fam et al., 2020). Formal research typically focuses on theoretical rigor and academic publication, while operational practices involving external stakeholders prioritize flexibility and immediate problem-solving. This pragmatic approach can sometimes conflict with the structured nature of academic research (Parrilli

& Heras, 2016). In the investigated project, aligning these two modes proved complex. Researchers struggled to shift from their traditional scientific roles to becoming facilitators of stakeholder engagement, a shift that required new skills and greater adaptability (Evans et al., 2015; Grunwald et al., 2024). Thomä (2017) highlights that incorporating DUI elements into STI-focused projects often necessitates a significant cultural shift within research teams (Grunwald et al., 2024).

In this project, some participants struggled with the concept of early stakeholder involvement, as they were accustomed to engaging stakeholders only in the final stages. This underscored the need for developing consensus within teams on how to balance scientific research with addressing socio-economic needs and expectations (Alcalde-Heras & Carrillo-Carrillo, 2024; Stål et al., 2022). Achieving this balance had a direct impact on the distribution of responsibilities, task division, and risk-sharing, making it a crucial factor for project success. To address these challenges, the project adopted a strategy of gradually evolving its network by expanding stakeholder circles, creating new relationships, and articulating emerging expectations. This began with the formation of a multidisciplinary team, followed by the incorporation of the CaLiLab's hybrid model of STI and DUI, and culminated in the inclusion of socio-economic stakeholders, which ultimately aligned the project with the Lab's hybrid strategy (Schuurman et al., 2016; Almirall & Wareham, 2008).

The project's use of the Living Lab methodology aimed to address these tensions by encouraging co-creation and iterative feedback between researchers and stakeholders (Schuurman et al., 2016). This approach significantly improved the recognition and understanding of stakeholder needs and provided a diverse informational foundation for the perspectives and expectations presented. As a result, it deepened the understanding of the project's complexity and highlighting its broader environmental and social impact (Mulgan, 2019). However, the CaLiLab itself is still in an emerging phase and is developing its tools for long-term stakeholder engagement. Moreover, administrative procedures and insufficient compensation highlight systemic barriers that undermine effective project execution (Isaksen & Nilsson, 2013; Grunwald et al., 2024). Constrained by university-level procedures and STI-based expectations, CaLiLab's support is currently limited to the structure of typical grant-funded research projects, which are often bound by stringent timelines. This structure has proven insufficient for addressing the complexities of inter and transdisciplinary collaboration, field experiments, and ongoing stakeholder engagement. For instance, the team expressed frustration over tight deadlines and the need to submit follow-up funding applications before fully evaluating the project outcomes (I1). Furthermore, the project's temporary nature poses a significant limitation, undermining efforts to build lasting trust with stakeholders and to sustain the developed innovations beyond the funding cycle (Bocken et al., 2019; Evans et al., 2015).

Despite challenges, the project's approach to knowledge transfer and social impact is significant. It utilized insights from stakeholders throughout the research process, technical innovation design, and supportive activities. Recognizing, aligning, and discussing these inputs took extensive effort, addressing concerns, distrust, misperceptions, and misinformation. This work was invaluable for developing sustainability-driven innovation at the university with environmental and social impact. However, it was time-consuming, requiring learning, new skills, and institutional support, which itself had to adapt. The integration of scientific findings into user-centred tools, like a web application, shows how STI and DUI can converge to produce actionable knowledge (Verhoef et al., 2019). Projects that blend formal research with practical application are better positioned to influence societal attitudes and behaviors toward sustainability (Alcalde-Heras & Carrillo-Carrillo, 2024; Caniglia et al., 2017). However, the project's reliance on temporary frameworks raises questions about its ability to establish lasting change, highlighting a gap between the literature's ideal of continuous improvement and the practical realities of project-based innovation (Brinkhurst et al., 2011).

## Integrating STI and DUI for urban biodiversity innovation

The integration of STI and DUI modes in the "To Mow or Not to Mow?" project was essential for fostering innovability—the capacity to create sustainable, socially responsible innovations. By combining the structured, data-driven approach of STI with the practical, user-focused insights of DUI, the project developed effective solutions for urban biodiversity management. This approach addressed both ecological and societal challenges associated with over-mowing, encouraging a shift away from conventional "mowing culture" toward more sustainable practices that enhance biodiversity. The Living Lab methodology facilitated continuous feedback between researchers and stakeholders, ensuring that the solutions were relevant, adaptable, and accessible to the community. This synergy exemplifies how blending formal scientific knowledge with experiential learning can drive innovations that are not only technologically sound but also aligned with the evolving needs of diverse stakeholders.

Moreover, the project's participatory approach strengthened community engagement and knowledge transfer. By involving local residents, NGOs, and public institutions, the project translated scientific findings into actionable

strategies. The co-creation process empowered stakeholders, ensuring that the project's outcomes were both scientifically valid and socially accepted. This integration of social and technological innovation demonstrates how urban biodiversity initiatives can leverage both STI and DUI modes to promote long-term sustainability and behavioral change in urban green space management.

Proposition 1: The **integration of STI and DUI modes** in sustainability projects **increases the diversity of knowledge inputs**, leading to more innovative and resilient biodiversity management solutions.

## New insights on university engagement and biodiversity

In the broader context, the academic community at Jagiellonian University shows strong support for biodiversity conservation, driven by two key factors. First, younger generations, including students, are acutely aware of the urgency for environmental protection, the consequences of climate change, and the necessity for proactive ecological actions. Second, the actual implementation of environmental protection policies, particularly on biodiversity and climate, is largely influenced by decision-makers at national, European, and global levels. However, local authorities are crucial for executing these policies effectively at a regional or municipal level. Jagiellonian University, as one of Poland's premier research institutions, is in a unique position to become a leader in advocating for these actions. It can initiate and promote measures rooted in rigorous scientific research, while also being open to the experiences and knowledge of stakeholders outside the academic sphere.

This combination of STI and DUI approaches aligns with the university's third mission—engaging with society and fostering collaboration with socio-economic entities. By merging academic insights with stakeholder-driven perspectives, the university can play a pivotal role in driving both theoretical and practical innovation. Achieving this balance, however, requires ongoing interdisciplinary collaboration and the recognition of external knowledge sources as equally valuable to traditional academic expertise.

Proposition 2: Universities that adopt a **dual STI-DUI engagement strategy** (scientific rigor + stakeholder co-creation) will have a **greater impact on biodiversity policy implementation** at the municipal level than those relying solely on traditional academic research dissemination.

## Addressing the tensions in integrating STI and DUI

The integration of STI and DUI modes is an evolving process rather than a ready-made framework for immediate implementation. As the *To Mow or Not to Mow?* project demonstrated, this process exposed tensions across ontological, epistemological, practical, and organizational dimensions. Natural scientists prioritized scientific rigor, while social scientists emphasized stakeholder engagement, leading to divergent research priorities. External stakeholders also held conflicting views on biodiversity management, creating friction between scientific recommendations and public preferences. These tensions were actively managed through a flexible stakeholder network and continuous dialogue, but this required time, effort, and openness to new contributions, placing additional demands on the project team.

The case of Jagiellonian University highlights the key role academic institutions can play in shaping biodiversity policies and fostering inter- and transdisciplinary collaboration. However, this approach requires navigating inherent tensions in knowledge production. Some participants initially struggled with the need for early stakeholder involvement, as engagement is often limited to the final stages of research. This underscores the importance of clear communication and structured collaboration to align scientific research with socio-economic and environmental needs. Achieving this balance influences how responsibilities are allocated, tasks are structured, and risks are managed throughout the project.

Proposition 3: The level of **epistemological and organizational tensions** in transdisciplinary research projects **decreases when stakeholder engagement is structured in progressive phases**, rather than introduced as a single-stage process.

## Practical and organizational challenges in integrating STI and DUI

Tensions arose from the strict timelines imposed by funding cycles, which conflicted with the iterative, adaptive nature of stakeholder-driven innovation. The project's temporary nature heightened stress for both researchers and stakeholders, as tight deadlines limited the flexibility needed for meaningful engagement. Researchers also faced the challenge of developing new skills in inter- and transdisciplinary collaboration and stakeholder management, yet this demand was not matched by adequate financial compensation. Administrative barriers, such as rigid institutional procedures, further

complicated project execution. While phased stakeholder engagement and iterative management helped mitigate some issues, institutional rigidity, financial constraints, and the project's temporary framework remain unresolved, restricting the full potential of STI and DUI integration.

These challenges highlight the need for institutions like Jagiellonian University to reform administrative procedures and establish better financial compensation structures for projects requiring inter- and transdisciplinary expertise. Greater flexibility in project timelines, sustained engagement, and iterative stakeholder feedback are crucial for ensuring long-term success in STI-DUI integration. Additionally, ongoing efforts are needed to build researchers' capacity to engage in hybrid projects, equipping them not only with technical research skills but also with expertise in stakeholder collaboration.

Proposition 4: The **long-term sustainability and effectiveness of transdisciplinary projects** integrating STI and DUI depend on **institutional flexibility in project management**, particularly in adapting funding structures, administrative processes, and **stakeholder engagement mechanisms** to support iterative and co-creative approaches.

## CONCLUSION

The findings from this study contribute to the ongoing theoretical debate on the relationship between STI and DUI modes of innovation, where some argue for their complementarity and others see them as substitutive. This research supports the complementarity view, showing that when integrated effectively, STI and DUI modes can mutually reinforce each other. In the "To Mow or Not to Mow?" project, the structured, data-driven knowledge of STI was enriched by the practical, stakeholder-driven insights of DUI, leading to more socially responsive and adaptive innovations in urban biodiversity management. This underscores the potential of hybrid innovation models to address complex challenges requiring both scientific rigor and practical flexibility, moving beyond the notion that these modes must remain distinct or competitive.

Moreover, the study advances the discussion on the dynamic interplay between these two modes by demonstrating how iterative stakeholder engagement—core to DUI—can enrich and reshape the scientific agenda set by STI. In this case, the inclusion of diverse non-academic perspectives did not dilute scientific rigor but enhanced the relevance and applicability of solutions, offering a practical demonstration of how both modes can operate synergistically. This finding suggests that under the right conditions, STI and DUI are not only compatible but can drive more impactful, sustainable innovations when combined effectively. The study also provides insights into managing the tensions that arise from integrating these modes, a challenge often overlooked in theoretical discussions.

From a practical standpoint, the project highlights the importance of flexible and adaptive project management approaches that allow for ongoing stakeholder input and iterative refinement of solutions. Organizations aiming to implement hybrid STI-DUI innovations must invest in capacity-building, ensuring that researchers possess both technical expertise and the skills needed for inter and transdisciplinary collaboration and stakeholder engagement. Furthermore, institutions should seek to reform rigid administrative procedures and improve financial compensation structures to better support projects requiring diverse skill sets and adaptive processes. Finally, this study underscores the necessity of sustained engagement and co-creation to secure long-term societal acceptance and successful implementation of innovations in biodiversity management.

Although the study provides valuable insights, it has certain limitations. Its reliance on a single case study focused on urban biodiversity management within a university setting may limit the generalizability of its findings. The context-specific approach may not fully capture the broader challenges of integrating STI and DUI modes across different sectors or regions. Additionally, the study's time-bound nature limited the ability to assess the long-term effects of these integrations, particularly in terms of sustained stakeholder engagement and the durability of outcomes beyond the project's funding cycle.

To build on these findings, extended studies are needed to explore the long-term societal impacts of combining STI and DUI modes, particularly in fostering ongoing community engagement. Further research into institutional barriers to inter and transdisciplinary collaboration could provide insights into developing more flexible organizational structures that better support innovability. Expanding the research into other sectors, such as private initiatives or diverse geographical regions, would offer a comparative understanding of how the balance between STI and DUI modes can be optimized across different innovation ecosystems.

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## Biographical notes

**Marta Najda-Janoszka** is an Associate Professor of Strategic Management at Jagiellonian University in Krakow, Poland. Her research focuses on the intersection of strategic management and entrepreneurship, with particular emphasis on the institutional perspective of value co-creation and capture dynamics within multi-stakeholder environments. She also conducts extensive studies on innovation, examining how innovative practices and policies impact strategic management and entrepreneurial activities. Her research aligns with a regional perspective, exploring how local contexts and regional policies influence business ecosystems and stakeholder interactions. She specializes in qualitative research.

**Joanna Kajzer-Bonk** is an Assistant Professor at the Department of Invertebrate Evolution, Faculty of Biology at Jagiellonian University in Krakow, Poland. She specializes in conservation biology and ecology of endangered blue butterflies, the flagship species for biodiversity conservation. She aims to uncover the crucial factors determining diversity loss in urban

and semi-natural areas and develop the tools for effectively protecting biodiversity. Member of the Jagiellonian University Climate Council and nature educator. She cooperates with Krakow non-governmental organizations.

**Ewelina Milewska** is a doctoral student at the Faculty of Management and Social Communication at Jagiellonian University in Krakow, Poland. She works as an Assistant at the Institute of Public Affairs at Jagiellonian University. Her research interests focus on marketing communication, management of higher education institutions, and intersectoral cooperation.

**Sylwia Wrona** is an Assistant Professor at the Institute of Public Affairs, Jagiellonian University in Krakow, Poland. Her research interests include the management of local non-governmental organizations, the development of civil society, and the role of culture and art in local communities. She conducts qualitative research, primarily using the assumptions of grounded theory, participatory action research, co-creation research, and case studies.

## Author contributions statement

**Marta Najda-Janoszka**: Conceptualization, Formal Analysis, Methodology, Discussion, Conclusions, Supervision, Writing Original Draft, Review & Editing. **Joanna Kajzer-Bonk**: Conducting Research, Data Providing/Resources, Review & Editing. **Ewelina Milewska**: Conducting Research & Data Curation, Coding & Categorization; Findings, Writing Original Draft, Review. **Sylwia Wrona**: Coding & Categorization, Findings, Writing Original Draft, Review & Editing.

## Conflicts of interest

The authors declare no conflict of interest.

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