Using Participatory GIS for Sustainable Campus Planning: Insights from GreenHack Hackathon

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Abstract
Climate change is the principal global challenge demanding active community participation alongside governmental and corporate efforts. This article presents findings from GreenHack, a student hackathon at Istanbul Technical University (ITU), utilizing Participatory Geographic Information Systems (PGIS) to enhance campus sustainability. Participants developed creative PGIS-based prototypes addressing green space planning, waste management, water conservation, and energy economy, aligned with UI GreenMetric standards and ITU's Green Campus project. These applications demonstrated GIS technologies' ability to visualize data, engage users through gamification, and provide actionable insights. GreenHack showcases the potential of participatory hackathons to connect sustainability goals with community engagement, offering scalable, inclusive frameworks for sustainable design extending from campus environments to broader urban contexts.

Keywords: Campus sustainability; Climate change; Green campus; Public GIS; Hackathon

Introduction

Cities have become areas facing many interconnected problems such as the side effects of industrialization, population density, and unhealthy urbanization. The damage to the environment due to these problems requires the integration of technology and sustainability to address these issues and for society to take action. Universities and their campuses are important for this goal because their physical structures, technological infrastructure, and qualified student populations carry the potential to create collective awareness and perform environmentally beneficial actions. As centres of learning and innovation, university campuses are ideal environments for adopting new approaches. Their focused communities and infrastructure enable them to effectively test and demonstrate sustainability and technology initiatives that can inform and inspire change in the wider city. Thus universities can set an example for adopting a green and sustainable design approach and adapting to changing dynamics. Many universities have adopted UN sustainable development goals within their curriculums and campuses. Their local and international connections give these institutions the opportunity to be effective in achieving these goals at different scales. Istanbul Technical University (ITU) has already demonstrated significant progress in these areas. For instance, its commitment to a green campus has earned global recognition, with ITU ranking in the top 50 in the 'UI Green Metric' ranking in 2025. Furthermore, it achieved a top 100 placement in 'The Impact Rankings,' which assesses sustainable development goals, sharing first place in Turkey with METU. These achievements are underpinned by its robust technological infrastructure, including efforts to integrate GIS-based applications with 'ITU Mobil'. Such initiatives not only enhance environmental consciousness but also foster active participation, transforming the campus into a dynamic model for observable sustainable practices and digital transformation.

This paper focuses on the 'Istanbul Technical University GIS-Based User-Oriented Green Campus Application Alternatives Determination' (İTÜ CBS Tabanlı Kullanıcı Odaklı Yeşil Kampüs Uygulama Alternatiflerinin Belirlenmesi)

project, supported by the Scientific Research Projects (BAP) unit. This BAP initiative specifically aims to develop user-oriented pilot applications for ITU's Green Campus activities, leveraging GIS and mobile infrastructures. Within the scope of this project, the GreenHack hackathon, organized at Istanbul Technical University (ITU) from December 1st to 3rd, 2023, served as a key activity. The hackathon was designed to bring together students, planners, GIS experts, and other stakeholders to collaboratively develop integrated Participatory Geographic Information Systems (PGIS) application prototypes. This event directly supported the broader goal of the BAP project by fostering creative, user-cantered solutions for ITU's 'Green Campus' initiative and enhancing the university's standing in the UI Green Metric rankings.

The hackathon itself was a participatory activity, as students are key stakeholders in the campus ecosystem and they were directly involved in shaping its future. By participating in the event, students had the opportunity to voice their perspectives, share their ideas, and contribute to creating solutions that reflect their priorities and needs. This collaborative environment also enabled them to acquire new knowledge and essential skills in areas such as GIS, urban sustainability, and app prototyping, through seminars and hands-on experience. This collaborative approach not only generated innovative prototypes but also fostered a sense of ownership and responsibility among participants, strengthening their connection to the campus and its sustainability goals.

Building on the identified need for innovative and participatory approaches to sustainable urban development, particularly within academic settings, this paper seeks to answer key questions regarding the efficacy of the GreenHack hackathon as a transformative planning action within the framework of a BAP project. Specifically, this study explores: How can hackathons, specifically utilizing Participatory GIS (PGIS), serve as an effective mechanism for fostering collaborative and innovative solutions for sustainable campus planning within a university context, as exemplified by the ITU Green Campus initiative? What types of PGIS-based solutions, in this case, prototypes, emerged from the GreenHack hackathon, and what is their potential for applicability within the UI GreenMetric criteria and scalability for addressing broader urban sustainability challenges, offering a replicable approach for other institutions?

To address these questions, the paper is structured as follows: Section 2 provides a comprehensive theoretical framework, reviewing the literature on participatory planning, the role of universities as living laboratories for sustainability, the evolution and application of Participatory GIS (PGIS), and the emergence of hackathons as platforms for collaborative innovation. Section 3 outlines the methodology, detailing the case study approach cantered on the GreenHack hackathon, data collection methods including document analysis and participant observation, and the analytical framework applied to the hackathon's outcomes. Section 4 presents the GreenHack hackathon as a detailed case study, describing its context within ITU's BAP project and Green Campus initiative, its structure, key themes, and the characteristics of the developed prototypes. Section 5 elaborates on the findings and analysis, discussing the innovation and functionality of the solutions, the role of PGIS in empowering stakeholder participation, and insights from the jury's evaluation. Section 6 offers a discussion of the broader implications of the GreenHack model, exploring its replicability and potential for scaling participatory solutions from campus to wider urban contexts. Finally, Section 7 concludes the paper by summarizing key arguments and contributions, emphasizing the transformative potential of participatory, technology-driven approaches in addressing contemporary environmental challenges[BDO2] .

Theory

From conventional, typically top-down, tactics to more sophisticated and diversified digital technologies, public involvement in urban planning has evolved significantly. Historically, public participation first surfaced in many industrialised nations in the middle of the 20th century when institutional planning frameworks were set up (Wilson and Tewdr-Jones, 2021). Early public participation mostly depended on representational democracy, when choices made by professional officials and elected politicians have less direct influence outside of local elections. Public criticism of expert-driven planning decisions intensified after the 1950s, which resulted in participatory democracy being more significant in planning choices (Campbell and Marshall, 2000). With the Skeffington report in 1969, which sought to change planning from something "done to people" to something "with people," this change was formalised in Britain. Arnstein's (1969) Ladder of Participation describes obstacles like incomprehensible technical and legal jargon, inflexible planning processes, and the over-representation of elite groups in participation, therefore showing how frequently early participatory attempts remained tokenistic despite these aims. With communicative and cooperative planning theories in the 1980s stressing public

involvement to oppose strong interest groups, the argument surrounding public participation changed (Forester, 1982). The notable transition to new technologies, referred to as the "digital turn," has commenced altering urban planning and public engagement in the planning process. Technology's impact on planning, including urban modelling and 3D visualisations, has been evident since the 1960s and 1970s to facilitate a scientific approach; however, its incorporation for public engagement is a more contemporary advancement. Planners initially exhibited reluctance in adopting the digital revolution, frequently perceiving it as beyond their area of expertise. The accessibility of digital technologies, especially through smartphones and social media, has significantly altered citizen interactions with government, impacting political discourse and campaigns (Batty, 2021). The increasing public demand, along with the constraints of conventional methods such as public hearings and written statements, has necessitated the development of more accessible and accountable planning processes. The COVID-19 pandemic expedited this transition, prompting local planning authorities to adopt digital working and engagement processes. During this digital transformation, various specific technologies have emerged. The Public Participation GIS (PPGIS) field has expanded considerably in the last ten years, acknowledging that GIS technologies possess both empowering and disempowering potential. PPGIS seeks to promote grassroots GIS applications through the integration of various local knowledge and participatory methods. This approach aims to modify GIS data structures to incorporate qualitative data, sketch maps, and images, in addition to quantitative data. This enhances the accessibility of complex spatial information. PPGIS techniques encompass collaborative mapping and community evaluation of spatial data (Sieber, 2000). The "SoftGIS" methodology in Finland serves as an internet-based PPGIS tool that gathers localised experiential knowledge from residents, including children. PPGIS has the potential to integrate expert and lay knowledge for mutual learning and is particularly effective in the early diagnostic phases of planning; however, challenges remain. The skills required and the significant financial and temporal costs associated with GIS use can exclude numerous individuals and groups. Concerns exist regarding the technology's tendency to prioritise quantitative and visual data, which may marginalise alternative forms of knowledge (Brown and Kyttä, 2014). Numerous PPGIS tools primarily offer information instead of promoting substantial engagement. The quality of spatial information gathered may be diminished if participants fail to allocate adequate time and effort to the mapping activity.

Mobile applications and social media platforms offer opportunities for "low-friction" and "in-situ" participation. Several apps have been designed to make people aware of proposed changes while they are physically in the built environment, allowing for quick, location-based comments and potentially influencing long-term planning policy. Social media serves as an informal platform for discussions related to place, reflecting individuals' lived experiences and providing a medium for commentary on observable changes (King and Brown, 2007). These platforms can expand discussions and engage individuals who are not typically involved in formal democratic debate (Twitchen and Adams, 2012; Wilson and Tewdwr-Jones, 2019). Exclusive reliance on applications and social media presents challenges, such as the digital divide and the potential exclusion of individuals who lack access to or confidence in using technology. Furthermore, many modern digital tools, similar to their offline equivalents, primarily facilitate one-way information distribution rather than fostering interactive dialogue (Conroy and Evans-Cowley, 2005). The speed and ease of participation, while beneficial for raising awareness and reporting issues, can sometimes undermine the quality and depth of comments, which may impede the acquisition of knowledge essential for long-term planning.

Approaches incorporating digital gaming and creative activities aim to encourage deeper, more reflective engagement. Technologies that allow people to express complex feelings and visions about their environment through drawing and talking provide a novel and tangible method for participation that moves beyond traditional text-based responses. These "serious games" are designed to make participatory processes more accessible and engaging by using game design techniques. Creative methods can allow a wider representation of people to include perspectives that digitized "traditional" technologies struggle to capture and help visual thinking about the future of places (Wilson and Tewdwr-Jones, 2019).Still, a major obstacle is bringing these innovative ideas into line with the formal, usually strict planning framework anchored in legal and procedural rules.

All things considered, digital technologies add extra complexity and reproduce certain current problems even if they provide chances to lower participation barriers and collect fresh points of view on urban development. Usually, the success of digital involvement depends on striking a balance between speed and efficiency with the depth and quality of interaction.Always in demand are a collection of solutions combining many digital and non-digital approaches aimed at certain planning activities and citizen needs.The ultimate aim is to produce citizen-

cantered involvement that guarantees that planning stays sensitive to the many experiences and ambitions of the people it serves and encourages significant communication.

The discussion on public participation in urban planning, particularly with the advent of new technologies, necessitates a deeper examination of 'equity' from both ethical and ecological perspectives. The historical evolution of planning participation reveals persistent issues of exclusion and unequal representation, where processes have often been "tokenistic" and dominated by specific, often more educated and affluent groups, or those with vested interests (Elwood, 2006) . This raises fundamental ethical questions about whose voices are heard and whose interests are served in planning decisions that affect a wide range of people. The planning system's traditional legalistic and technical language, coupled with its top-down, expert-driven nature, has historically disenfranchised many citizens, especially those in lower-income socio-demographic groups, ethnic minorities, and women, who are typically less involved in decision making (Arnstein, 1969; Forester, 1982). This inherent bias means that the rights of the minority often disappears once the majority has spoken. The input of these stakeholders can be omitted also due to dominant cultural norms and values that define legislation and planners' attitudes. From an ethical standpoint achieving genuine equity requires addressing these deeply rooted power imbalances and moving towards a more human-cantered approach that values diverse lived experiences and emotions, rather than solely focusing on the technical and procedural aspects of land use.

The concept of equity is also combined with ecological considerations especially within the broader discourse of sustainable development. While sustainable urban planning aims to create environments that are equitable, efficient, and resilient, there is often a tension between these goals (Wilson and Tewdwr-Jones, 2019). Particularly between economic growth and social equity or growth and environmental sustainability. For instance, the government may interpret "sustainable development" as economic growth and job creation, sometimes disregarding or minimizing important issues like climate adaptation, environmental protection, and resilience. Decisions on major projects such as airports or new housing often involve hard trade-offs between regional economic benefits, local quality of life and environmental costs. Achieving "environmental justice" requires that planners consider how their decisions may lead to inequitable distributions of environmental costs particularly for communities at risk. Therefore, a "just city" model emphasizes a collective identity that promotes diversity while supporting values such as democracy, equity, growth, and sustainability (Fainstein, 2005) ensuring that no single value is above others with equity being at the forefront.

From ethical as well as environmental perspectives, new technologies have a complicated and changing role in tackling equitable issues. Digital tools—including Public Participation GIS (PPGIS), applications, and social media—offer great chances to lower obstacles to participation by means of time and geographic restrictions, and by including those who do not usually engage in conventional planning procedures. PPGIS can locate cultural ecosystem services and social-ecological "hotspots" offering a geographical way to combine many values into environmental planning (Alessa et al, 2008). These technologies, however, can bring fresh ethical questions and potentially "exacerbate previously existing digital and representation disparities" (Wilson & Tewdwr-Jones, 2019, p. 161). Although technology presents a strong tool for increasing citizen involvement and openness, it needs careful design to guarantee inclusivity, balance various forms of knowledge and honestly empower communities to shape their surroundings in a more just and sustainable way, rather than just digitising current often unfair processes.

Increasingly acknowledged as effective citizen centred projects encouraging cooperation among many people to provide creative answers to public challenges are hackathons. These fast-paced, design-driven events unite people from several backgrounds—technical specialists, designers, and non-programmers—to turn ideas into real-world prototypes within designated timesframes (Falk Olesen and Halskov, 2020). While conventional crowdsourcing usually sees participants working independently on ideas, hackathons—especially those aimed at civic engagement—aim to encourage generative co-creation and collaborative discourse, whereby participants build upon each other's ideas to develop more complete solutions. This method leverages the "wisdom of people" and varied experience to provide a range of ideas that would not result from more expert led initiatives (Surowiecki, 2012). The objective is not just to produce plenty of ideas but also to deepen knowledge of issues and support original, creative solutions going beyond product innovation towards support of society impact.

Using hackathons to actively solve important environmental issues is under more and more importance. Combining end users, technological professionals, students, and citizens, these "green hackathons" address environmental challenges and support reflective practices and practical solutions (Adisa et al., 2023). Often functioning as "living laboratories," universities are very important in this regard as they use their people resources and capital to create test beds for Sustainable Development Goal (SDG) solutions (Purcell et al., 2019). Hackathons encourage multidisciplinary cooperation and inspire participants to create creative digital solutions that propel sustainable actions and environmentally friendly initiatives, including lowering CO2 emissions or supporting sharing economies, by tying academic knowledge with practical sustainability problems. These projects help to empower people economically and modify behaviour in addition to increasing sustainability consciousness and encouraging a green attitude among participants and society. By means of prototype creation, the group participation in local sustainability challenges emphasises the possibilities of hackathons to directly influence society well-being and hasten towards more general sustainable development objectives.

Method

This study employs a qualitative, in-depth case study approach to examine the GreenHack event as a model for participatory GIS (PGIS) in sustainable campus planning. In this research the GreenHack hackathon serves as the primary case. This approach allowed for an in-depth investigation into how participatory methodologies, specifically a hackathon utilizing PGIS, can empower stakeholders and generate actionable solutions for sustainable campus planning.

The research design for this paper centres on an in-depth case study of the GreenHack hackathon, held at Istanbul Technical University's Faculty of Architecture from December 1st to 3rd, 2023. The hackathon was specifically designed to support ITU's "Green Campus" initiative and enhance its standing in the UI Green Metric rankings by developing integrated PGIS application prototypes. The focus was on leveraging technology, creativity, and participatory design to contribute to environmental sustainability efforts at ITU.

The case study design enabled a comprehensive analysis of the hackathon as a "living lab" for sustainability, where students, as key stakeholders, were directly involved in co-creating solutions for their campus environment. This qualitative approach allowed for the exploration of the nuanced interactions between participants, the challenges they identified, and the innovative solutions they proposed within the specific context of ITU's sustainability goals. The dynamic nature of a hackathon, characterized by intensive collaboration and rapid prototyping, provided a unique setting to observe and analyse participatory innovation in action.

Data for this case study were primarily collected through two main methods: document analysis and participant observation.A comprehensive review of various official documents related to the GreenHack hackathon and ITU's sustainability initiatives was conducted. This included the GreenHack Booklet which provided detailed information on the event's concept, objectives, structure, themes (green spaces, waste management, energy efficiency, water conservation, participatory GIS), program flow, expected outcomes, key elements, evaluation criteria, jury composition, mentorship, and awards; the Jury Report which provided insights into the evaluation criteria and specific comments on the strengths and weaknesses of the submitted projects, particularly the three winning projects; BAP Project application and Progress Reports: These internal ITU documents provided the foundational rationale for the project, its objectives, planned methodologies, and updates on its progress.

The final part of the analysis focused on Project Submissions (Prototypes and Concept Descriptions). The outputs from the hackathon teams, including their PGIS application prototypes and detailed concept descriptions, provided concrete examples of the proposed solutions. Participants were instructed to use pseudocode and graphic narrative techniques (e.g., screen designs, diagrams, symbols, colours, animations) to present their prototypes, detailing the application's purpose, target audience, data and methods, and expected outcomes. They were also required to align their concepts with UI Green Metric criteria and ITU Green Campus objectives.

Findings

Istanbul Technical University (ITU) is actively committed to integrating environmental sustainability into its operations and campus design, a commitment underscored by its "Green Campus" initiative. This project aims to transform ITU's Ayazağa campus into an environmentally conscious, smart, and liveable space that prioritizes nature, conserves resources, and enhances the quality of life for its community. The ITU Green Campus initiative,

launched in 2008, emphasizes a respectful approach to both nature and people. Key features include preserving natural habitats, creating pedestrian and bicycle routes, and implementing solutions for individuals with disabilities, aligning with the "Accessible ITU" motto. Specific actions involve sustainable landscape design with high water permeability for hard surfaces, use of low-water-consuming and climate-appropriate vegetation, and optimized irrigation and lighting systems. Furthermore, the campus has increased its green area, developed a greenhouse gas inventory, expanded bicycle paths to a target of 6 kilometres, established a bicycle repair and sales shop, installed electric vehicle charging units, and implemented separate collection of rainwater for a campus pond.

ITU's dedication to sustainability is also reflected in its strong performance in global university rankings. In 2021 ITU ranked 31st among 100 universities in Europe and 57th globally out of 956 universities in the UI Green Metric ranking system. Nationally, ITU holds the leading position in green campus initiatives in Türkiye. The UI Green Metric established by Universitas Indonesia in 2010 evaluates universities' environmental performance and sustainability across six main criteria: Setting and Infrastructure, Energy and Climate Change, Waste, Water, Transportation, and Education and Research. In the 2020 UI Green Metric country rankings ITU excelled in education, transportation, and waste management categories. Beyond UI Green Metric, ITU also featured in "THE Impact Rankings," which assess universities' contributions to the UN Sustainable Development Goals. In 2021, ITU was ranked in the 101-200 range globally among 1117 universities in THE Impact Rankings, sharing Turkey's top position with Abdullah Gül University. The university's strategic plan (2017-2021) explicitly emphasizes ITU's transformation into a green campus, with specific goals such as reducing carbon footprint and achieving 100% UI Green Metric certification by 2020.

The GreenHack hackathon was an innovative event designed to promote student-driven solutions for campus sustainability. Held at the ITU Faculty of Architecture's Taşkışla Campus, the event aimed to bolster the "ITU Green Campus" initiative and improve the university's standing in the UI Green Metric rankings. The hackathon received applications from a total of eight student groups. Out of these, six groups actively participated in the hackathon and successfully submitted their projects in the required format. Participants were divided into interdisciplinary teams of 4-6 individuals, fostering a collaborative environment with diverse skills to address various facets of the challenge. The target audience for GreenHack included students from various ITU faculties, such as urban planning, architecture, and computer engineering.

The GreenHack hackathon was designed to foster civic engagement, encourage generative co-creation, and promote collaborative discourse among participants in developing sustainable campus solutions. The event, spanning three days from December 1st to December 3rd, 2023, at ITU's Taşkışla Campus, incorporated several key elements to facilitate this "wisdom of crowds" approach.

The initial phase, Day 0 (December 1st), began with a registration period, followed by a seminar focusing on Green Campus initiatives, Participatory GIS (PGIS), and mobile applications. This seminar served as an foundational element, providing participants with a common understanding of the core concepts and tools necessary for the hackathon's objectives. By equipping all teams with essential knowledge in GIS, urban sustainability, and app prototyping it ensured a baseline understanding upon which collaborative efforts could build. The next session for hackathon team introductions and a Q&A segment directly promoted initial interactions and the sharing of preliminary ideas among participants, laying the groundwork for collaborative discourse. The official kickstart of the 24-hour hackathon on the evening of Day 0 immediately immersed teams in an intensive co-creation environment.

Day 1 (December 2nd) was dedicated entirely to the core development phase, with the critical introduction of mentor participation. Mentors, experienced in GIS technology, urban planning, and app development, provided direct guidance and support, facilitating problem-solving and encouraging the refinement of ideas through expert feedback. This mentorship model allowed teams to benefit from diverse perspectives and build upon their initial concepts with informed input. Through informal breaks the event provided organic opportunities for inter-team discussion and sharing of ideas, contributing to the generative nature of the event.

The final day (December 3rd) featured a projects video sharing and award ceremony, which served as a platform for teams to present their developed solutions to a broader audience. This public presentation aspect is vital for civic

engagement, allowing for the dissemination of innovative ideas and fostering a sense of collective achievement. The subsequent networking session between teams, juries, and the project team further encouraged continued collaborative discourse and the potential for future development of the concepts generated during the hackathon. The overall structure of GreenHack, from foundational seminars to intensive collaborative development and public presentation, was designed to harness the collective intelligence of participants, leading to more comprehensive and actionable solutions for campus sustainability.

The GreenHack event was not only about technology and sustainability but also embodied these principles in its prizes and operational aspects, effectively "closing the loop" on its core themes. The prizes were strategically designed to reinforce the hackathon's dual focus. All winning team members received free registration for ESRI ArcGIS Pro training (face-to-face or online). This particular prize directly advanced technological skill development in GIS, a fundamental tool for sustainable planning, ensuring that the acquired knowledge from the hackathon could be further honed and applied in professional contexts. Furthermore, the event explicitly incorporated sustainability into its material outcomes. The hackathon featured a 3D work produced from waste materials. This contribution represented a technical innovation in the application of sustainable practices. It showcased an innovative approach to upcycling and material reuse, involving advanced design and fabrication methods for transforming discarded materials into a valuable, three-dimensional product. This initiative physically demonstrated the principles of a circular economy and waste reduction that the hackathon aimed to promote, moving beyond theoretical concepts to embodied, tangible solutions. By integrating this demonstration of sustainable production into the event, GreenHack reinforced the practical application of sustainable practices. All participating teams also received a Certificate of Participation, recognizing their contribution to an event dedicated to environmental sustainability. This comprehensive integration of tech-centric skill development and direct sustainability practices into the event's incentives and physical presence ensured that GreenHack served as a holistic demonstration of its central themes.

The Winning PGIS Entries

The intensive, collaborative nature of the hackathon facilitated interdisciplinary collaboration, motivating participants to develop innovative digital solutions aimed at driving sustainable actions and environmentally friendly initiatives on campus. The participants were tasked with developing PGIS application prototypes and concepts that could be integrated into the existing ITU Mobile application. This requirement specifically promoted the development of digital solutions that could seamlessly translate into real-world sustainable actions for ITU. The projects were evaluated based on their innovation, functionality, design, and impact, ensuring that the proposed solutions were not only creative but also practical and aligned with tangible sustainability goals.

Three winning prototypes emerged from the GreenHack hackathon, each offering a unique approach to enhancing campus sustainability through participatory GIS: Green Tracker (First Prize), BeeKe (Second Prize), and Green Bee Systems (Third Prize). These projects demonstrate how hackathons can connect academic expertise with real-world sustainability problems, encouraging innovative digital solutions that range from reducing waste and promoting sustainable mobility to fostering a sharing economy mindset. Each prototype included technical aspects, such as data collection, spatial analysis, and application development, in addition to social aspects by encouraging behavioural change, community engagement, and collaborative problem-solving.

Green Tracker: A Comprehensive Environmental Monitoring Tool

Green Tracker, the first-prize winning project, was designed to track and improve environmental sustainability efforts within the ITU campus. Its primary goal was to enhance the environmental consciousness of individuals residing in or using the campus and to encourage their active participation in sustainable practices. The project specifically targeted critical areas such as waste management, energy consumption, green space preservation, and air quality, enabling users to monitor and share their observations and proposed solutions. The project focused on the challenges of campus environmental management by providing a platform for real-time feedback and engagement. By focusing on data collection related to specific environmental parameters Green Tracker aimed to create a more transparent and accountable system for understanding and mitigating the campus's environmental footprint. This objective directly aligns with ITU's aim of becoming a greener university and improving its environmental performance.

Green Tracker used mobile application platforms and Geographic Information Systems (GIS) to integrate data from both campus users and the university's official sources. The prototype provided a user-friendly interface that facilitated map-based participation, allowing individuals to pinpoint and report environmental issues directly on a digital map of the campus. This spatial data collection mechanism is a core component of PGIS, enabling the visualisation and analysis of geographically referenced information. The application's design conceptually included pseudocode to detail the algorithmic steps for data input, spatial querying, and updating user scores based on their contributions. Graphic narrative techniques such as screen designs and diagrams, were used to illustrate how environmental observations, proposed solutions and activities would be visually represented within the application's interface. This dual approach ensured a clear communication of both the technical functionality and the user experience of the PGIS application.

The project was successful promoting active user engagement and participation which is a critical aspect that enables equity within campus sustainability initiatives. By employing gamification elements like a scoring and reward system Green Tracker promoted eco-friendly behaviours making participation accessible and appealing to a diverse range of campus users. The dual role of PGIS, helping as a technical instrument for data visualisation and spatial analysis while also functioning as a participatory mechanism that encourages stakeholders in shaping campus sustainability initiatives, was effectively illustrated through the GreenHack prototypes. This crowdsourcing approach democratizes environmental monitoring and problem identification enabling individuals from various backgrounds to contribute their local knowledge and perspectives, thus tapping into the "wisdom of crowds."

Green Tracker was recognized by the jury as innovative, effective in ensuring active user participation, and providing the most comprehensive and positive contribution to sustainable objectives. Its value proposition lies in offering a holistic tool for environmental monitoring and community-driven action, fostering a bottom-up approach to sustainability. The innovative use of gamification to drive civic engagement for environmental good sets a precedent for how digital tools can empower individuals to become active stewards of their surroundings.

BeeKe: Gamifying Sustainable Mobility

BeeKe, the second-prize winning project, was developed to significantly promote the use of bicycles and scooters within the ITU Maslak Campus. The initiative aimed to encourage campus residents, particularly students and academic staff, to adopt sustainable transportation modes, thereby contributing to a reduction in the campus's carbon footprint and fostering healthier commuting habits. The project promoted sustainable transportation adoption by introducing an engaging and rewarding incentive mechanism. By focusing on specific behavioural changes related to mobility BeeKe aimed to integrate eco-friendly choices into the daily routines of campus members moving beyond mere awareness to active participation in sustainable practices.

BeeKe used Geographic Information Systems (GIS) and Internet of Things (IoT) devices to contribute to making campus transportation greener and more sustainable. The application had a points system that incentivized sustainable mobility behaviours such as correctly parking bicycles. The project also included a feedback mechanism for bicycle paths, encouraging users to report issues or suggest improvements directly through the mobile application. The pseudocode for BeeKe outlined the logic for tracking bicycle and scooter usage, calculating points based on distance or compliant parking and managing the gamified reward system. The graphic narrative displayed the in-app interface for tracking rides, viewing accumulated points, and accessing a leaderboard, making the sustainable commuting experience interactive and competitive.

BeeKe's strength was its innovative use of gamification to drive user engagement in sustainable mobility. By providing a tangible reward system for eco-friendly actions, it aimed to make participation accessible and appealing to a broad spectrum of campus users, encouraging active adoption of sustainable transportation modes. The feedback mechanism for bicycle paths also allowed for direct user input on infrastructure improvements, fostering a sense of co-ownership in shaping the campus's sustainable mobility landscape and ensuring that the needs of all users were considered.

The jury found the project successful, acknowledging its innovative approach to promoting sustainable transportation through gamification. While its strong focus on mobility was noted, the effective use of a clear system algorithm and its impact on encouraging greener commuting habits were particularly appreciated.

The project's capacity to incentivize and engage users in real-time contributes to a more equitable and participatory approach to campus sustainability.

Green Bee Systems: A Social Platform for Sustainability

Green Bee Systems, the third-prize winning project was developed to support and enhance green and sustainable initiatives across the ITU Maslak Campus. Its core objective was to facilitate active participation from all segments of the ITU community including students, academics, administrative staff, student clubs, alumni, and retired faculty in sustainability-related data and projects.

The platform aimed to overcome information disconnect and foster a more connected and proactive campus community regarding environmental issues. By creating a centralized hub for sustainability efforts, Green Bee Systems aimed to empower individuals to contribute their observations, share their projects and collaborate on collective solutions to campus environmental challenges.

Green Bee Systems included a user-friendly platform, similar to a social media network, and utilized Geographic Information Systems (GIS) infrastructure alongside mobile and web platforms, data analysis, and visualization tools. A key technical feature was its ability to integrate official university data with location-based data provided by users. This hybrid data integration allowed for a comprehensive spatial understanding of sustainability initiatives on campus.

The project's design included features for data collection and input, mapping and visualization, community participation, and project collaboration development. Users could share their sustainability observations and projects through the platform and contribute to other ongoing initiatives. The pseudocode outlined the backend logic for managing user-generated content, linking it to spatial data, and facilitating communication and collaboration features, while graphic narratives illustrated the social feed, interactive map, and project pages.

The core strength of Green Bee Systems lay in its strong emphasis on community engagement and project collaboration, effectively creating a "social media platform" for sustainability. By enabling all ITU constituents to share observations and contribute to projects, it democratized access to sustainability initiatives and fostered a profound sense of collective action and ownership. This participatory approach is fundamental for ensuring that sustainability efforts are inclusive and genuinely reflect the diverse needs and priorities of the entire campus community, thus promoting equity by giving every stakeholder a voice in shaping the campus's future.

The jury commended Green Bee Systems for its well-designed information flow and database and its effectiveness in facilitating user communication. Its value proposition cantered on creating a centralized, interactive hub for sustainability initiatives, fostering a more connected and proactive campus community. The innovative integration of social media dynamics with PGIS offers a unique model for broad-based civic engagement in environmental protection.

SDGs

The winning prototypes from the GreenHack hackathon demonstrate a strong alignment with both the UI Green Metric criteria and the broader United Nations Sustainable Development Goals (SDGs), showcasing the university's role as a "living lab" for real-world sustainability solutions. Green Tracker, with its focus on waste management, energy consumption, and air quality, directly contributes to UI Green Metric's categories of Waste (WS) and Energy and Climate Change (EC). Furthermore, its objective to increase environmental awareness and encourage active participation aligns with SDG 12: Responsible Consumption and Production by fostering sustainable practices, and SDG 13: Climate Action by addressing energy and air quality. The project's emphasis on user observations and solution sharing also supports SDG 4: Quality Education by promoting sustainability literacy within the campus community.

BeeKe, by promoting bicycle and scooter use, directly addresses the UI Green Metric's Transportation (TR) criterion. This initiative directly contributes to SDG 11: Sustainable Cities and Communities by fostering sustainable transportation options, and indirectly to SDG 13: Climate Action by reducing carbon emissions associated with commuting. The gamified approach to encouraging behavioural change also touches upon aspects of promoting sustainable lifestyles under SDG 12. Green Bee Systems, functioning as a social platform for sustainability initiatives,

broadly supports all UI Green Metric criteria by enhancing awareness, facilitating collaboration, and integrating diverse data. Crucially, its emphasis on broad participation from all ITU constituents; students, staff, and faculty and directly reinforces SDG 17: Partnerships for the Goals, by building inclusive multi-stakeholder partnerships for sustainable development. Furthermore by providing a platform for sharing sustainability-related data and projects it contributes to SDG 4: Quality Education by disseminating knowledge and encouraging sustainability research and innovation. The prototypes collectively demonstrate how localized, technology-driven, and participatory solutions within a university setting can effectively advance global sustainability agendas.

Discussion

The GreenHack hackathon provided rich insights into the potential of participatory methodologies and GIS-based tools for addressing complex sustainability challenges within a university campus setting. The event successfully functioned as a "living lab," demonstrating how the collective intelligence of students, guided by academic and technical expertise, can generate innovative and actionable solutions.

The three winning prototypes: Green Tracker, BeeKe, and Green Bee Systems demonstrated innovation and functionality in addressing diverse sustainability challenges on the ITU campus. Green Tracker's approach moved beyond passive data reporting to actively incentivize and reward eco-friendly behaviours, thereby promoting a more proactive and engaged campus community in environmental monitoring and problem-solving. Its functionality revolved around intuitive data collection, sharing, and visualization, directly linking user actions to measurable sustainability impacts. BeeKe demonstrated innovation in sustainable mobility by gamifying bicycle and scooter usage. Their direct behavioural intervention, supported by a feedback mechanism for bicycle paths, aimed to shift commuting habits towards more environmentally friendly modes. Green Bee Systems, on the other hand, presented a broader social platform for sustainability. Its functionality focused on enabling wide-ranging participation from all ITU constituents in sustainability projects and data sharing, effectively serving as a social media-like hub for environmental initiatives. This platform's innovation lay in fostering collaborative project development and knowledge exchange, making sustainability a collective and highly interactive endeavour. Each prototype, while distinct in its primary focus, leveraged digital functionalities to make sustainability engagement more accessible, measurable, and engaging for the campus community. These ideas show how participatory design may effectively combine technical features with social interventions, therefore promoting not just technology innovation but also cultural and behavioural changes towards sustainability.

Participatory Geographic Information Systems (PGIS) proved to be a key element in empowering student participation and co-creation during the GreenHack hackathon. In GreenHack, students were provided with campus-related maps and land use data, transforming them from passive recipients of information into active contributors to a shared spatial understanding of campus sustainability. Green Tracker exemplifies this empowerment, allowing users to geographically pinpoint environmental issues and share solutions on a map, thereby democratizing the identification and visualization of campus challenges.

The requirement for prototypes to be compatible with ITU Mobile also meant that PGIS functionalities were designed to be user-friendly and widely accessible. This lowered the barrier to participation, enabling a larger segment of the student body to contribute their observations and ideas in a spatially intelligent manner. BeeKe's feedback mechanism for bicycle paths and Green Bee Systems' integration of location-based user data further highlight how PGIS empowered students to not only report but also actively shape and improve the physical and operational aspects of their campus environment. This direct engagement with geospatial data fostered a sense of agency among participants, aligning with the broader goal of democratizing spatial knowledge in planning processes.

Beyond the PGIS tools, the very structure and execution of the GreenHack event promoted the hackathon as a participatory process, focusing on student voices and fostering a deep sense of ownership. The event commenced with a comprehensive seminar that provided a common knowledge base on green campus concepts, PGIS, and mobile applications, ensuring that all participants were equipped to contribute meaningfully. This structure enhanced ownership and responsibility among participants, as students became partners of solutions, thus deepening their engagement with the campus's sustainability goals. This was critical for cultivating an environment where ideas could genuinely build upon each other, leveraging the "wisdom of crowds."

The inclusion of experienced mentors throughout the development phase was key in guiding participants and promoting the refinement of their ideas. This continuous feedback loop encouraged generative co-creation, where initial concepts evolved through expert input and inter-team discussions. As highlighted in a related social media article, "Hacking for Sustainability: How Students Are Redefining Our Future, One University Campus at a Time," the event's atmosphere fostered a collective drive, where students actively shaped solutions reflecting their priorities and needs, thus strengthening their connection to the campus's sustainability goals. The culminating video sharing and award ceremony served not only as a presentation platform but also as a celebration of this collective effort, further cementing a sense of ownership over the proposed innovations.

The jury's evaluation of the GreenHack prototypes provided crucial insights into the potential and pitfalls inherent in student-led innovation within a hackathon framework. The assessment criteria: Innovation, Functionality, Design, and Impact, were applied rigorously, highlighting both the strengths and areas for improvement in the submitted solutions. The evaluations also pointed to potential pitfalls. The insights from the jury underscore the balance required between innovative conceptualization and practical implementability, particularly regarding resource allocation and system integration, which are common challenges in transitioning hackathon prototypes to large-scale deployment.

The GreenHack hackathon, while specifically designed for the ITU campus, offers a model for scaling participatory solutions to broader urban contexts. The GreenHack model presents a highly replicable framework for participatory planning that extends beyond the university campus to wider urban settings. Its core strength lies in the synergistic integration of PGIS technology, the intensive hackathon format, and a deliberate focus on interdisciplinary collaboration. By providing foundational knowledge through seminars, offering continuous mentorship, and fostering a competitive yet collaborative environment, GreenHack effectively cultivated a space for generative co-creation. This approach, which actively engages end-users and diverse stakeholders in problem identification and solution development, directly taps into the "wisdom of crowds," generating solutions that are both innovative and locally relevant. The emphasis on developing digital prototypes (PGIS applications) ensures that the outputs are inherently scalable and can leverage existing mobile infrastructure, similar to ITU Mobile, for wider dissemination and impact.

The success of prototypes like Green Tracker, which uses map-based reporting and gamification for environmental monitoring, and BeeKe, which incentivizes sustainable behaviour, demonstrates that such user-cantered, technology-driven solutions are not limited to campus boundaries. These models can be adapted for city-wide waste management initiatives, public transport optimization, or urban green space planning. Green Bee Systems further highlights the potential for building community-wide social platforms for sustainability, fostering collective action across a diverse urban population. By systematically structuring the problem-solving process, providing necessary technical resources and guidance, and valuing direct citizen input, the GreenHack model offers a robust and adaptable framework for urban planners and policymakers seeking to implement more inclusive, effective, and scalable participatory planning initiatives for a sustainable future.

Conclusion

This research examines the GreenHack hackathon as a participatory framework for integrating digital technologies, especially Participatory Geographic Information Systems (PGIS), into sustainable campus design at Istanbul Technical University (ITU). The findings indicate that hackathons can be helpful in promoting community participation, innovation, and collaboration in addressing complex sustainability challenges. The three winning prototypes—Green Tracker, BeeKe, and Green Bee Systems—demonstrated how PGIS-based solutions can encourage active participation, promote environmentally responsible behaviours, and facilitate knowledge sharing across a diverse campus community.

The GreenHack event functioned not only as a technical exercise but also as a social and educational process, enabling students to become co-creators of their campus's sustainable future. Combining gamified digital tools, mentoring, and multidisciplinary cooperation, the hackathon succeeded in enabling participants to create meaningful solutions that meet UI Green Metric standards and help the United Nations Sustainable Development Goals (SDGs). Furthermore, the scalable nature of these digital prototypes emphasises the potential to apply such participatory strategies beyond the university into wider metropolitan environments.

In conclusion, GreenHack demonstrates that the integration of PGIS and participatory hackathons can bridge the gap between environmental objectives and community engagement, offering a replicable model for inclusive, innovative, and impactful planning practices. Involving students as participants of sustainability solutions enhanced their sense of ownership and strengthened their commitment to long-term environmental objectives. Future research could explore the long-term implementation of such prototypes and assess their effectiveness in driving sustainable behaviour and institutional change.

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References

Adisa, M.O., Oyedeji, S., Porras, J., Abdullai, L. and Lau, S.L., 2023, June. SustHack: A Hackathon approach for Engaging Citizens and Fostering a Sustainability Mindset. In TKTP (pp. 116-127).

Alessa L., Kliskey, A. and G. Brown, 2008. Social–ecological hotspots mapping: a spatial approach for identifying coupled social–ecological space. Landscape and urban planning, 85(1), pp.27-39.

Arnstein, S.R., 1969. A ladder of citizen participation. Journal of the American Institute of planners, 35(4), pp.216-224.

Batty, M., 2021. The digital transformation of planning. Environment and Planning B: Urban Analytics and City Science, 48(4), pp.593-597.

Brown, G. and Kyttä, M., 2014. Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research. Applied geography, 46, pp.122-136.

Campbell, H. and Marshall, R., 2000. Moral obligations, planning, and the public interest: a commentary on current British practice. Environment and Planning B: Planning and Design, 27(2), pp.297-312.

Conroy, M.M. and Evans-Cowley, J., 2005. Informing and interacting: The use of e-government for citizen participation in planning. Journal of E-Government, 1(3), pp.73-92.

Elwood, S., 2006. Negotiating knowledge production: The everyday inclusions, exclusions, and contradictions of participatory GIS research. The Professional Geographer, 58(2), pp.197-208.

Falk Olesen, J. and Halskov, K., 2020, July. 10 years of research with and on hackathons. In Proceedings of the 2020 ACM designing interactive systems conference (pp. 1073-1088).

Fainstein, S.S., 2005. Cities and diversity: Should we want it? Can we plan for it?. Urban affairs review, 41(1), pp.3-19.
Forester, J., 1982. Planning in the Face of Power. Journal of the American planning association, 48(1), pp.67-80.

Kahila-Tani, M., Broberg, A., Kyttä, M. and Tyger, T., 2016. Let the citizens map—public participation GIS as a planning support system in the Helsinki master plan process. Planning Practice & Research, 31(2), pp.195-214.

King, S.F. and Brown, P., 2007, December. Fix my street or else: using the internet to voice local public service concerns. In Proceedings of the 1st international conference on Theory and practice of electronic governance (pp. 72-80).

Purcell, W.M., Henriksen, H. and Spengler, J.D., 2019. Universities as the engine of transformational sustainability toward delivering the sustainable development goals: "Living labs" for sustainability. International Journal of Sustainability in Higher Education, 20(8), pp.1343-1357.

Sieber, R.E., 2000. Conforming (to) the opposition: the social construction of geographical information systems in social movements. International Journal of Geographical Information Science, 14(8), pp.775-793.

Surowiecki, J., 2012. The wisdom of crowds. Abacus.

Suwartha, N. and Sari, R.F., 2013. Evaluating UI GreenMetric as a tool to support green universities development: assessment of the year 2011 ranking. Journal of Cleaner Production, 61, pp.46-53.

Twitchen, C. and Adams, D., 2012. Using web technology to increase levels of public participation in planning. Town Planning Review, 83(6), pp.vii-xiv.

Wilson, A. and Tewdwr-Jones, M., 2021. Digital participatory planning: Citizen engagement, democracy, and design. Routledge.