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Campus Changer: A Serious Geogame for Transforming the Main Campus of the Warsaw University of Technology

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Abstract

The goal of the article was to develop a serious geogame that allows for the activation of the Warsaw University of Technology's (WUT) academic community's involvement in the participatory planning process for campus revitalization and development. The Campus Changer geogame is implemented as a PC-based application that uses a detailed 3D model of the WUT campus and the players' real-time physical location. The geogame allows not only virtual exploration of a detailed, 3D model of the university campus but also raises awareness of the problems associated with the functioning of the members of the academic community in a jointly used space. The Campus Changer geogame, developed using the Unity engine with detailed WUT campus models (LoD [level of detail] 3), allows users to explore the campus and propose transformations. Guided by Genius Loci, the university's guardian spirit, players encounter challenges and interact with diverse campus stakeholders, such as academic staff, students, and local residents. Player decisions reshape the campus instantly, with changes visible in the 3D virtual world. The Campus Changer geogame allows users to manipulate detailed geospatial data (a 3D model of the WUT campus and its connection to GIS tools) and can be used as a powerful geoparticipation tool. The results of GIS analyses conducted by the authors of the article using data collected based on the results of a multi-player game provide insight into the opinions of different groups of the WUT academic community, who propose diverse changes in different parts of the campus. Compared to traditional planning consultations, the geogame

facilitates the collection of input from a significantly broader and more diverse audience, fostering inclusive and participatory decision-making. The most significant achievement of the project is the activation of the academic community and co-creation planning for the modernization and development of the university.

Keywords
co-creation; gamification; geogame; location-based game; participatory democracy; serious game

1. Introduction

Modern university campuses of leading universities not only play a crucial role in creating an environment for research and education at the highest level but also in supporting the formation of the academic community. Beginning with Plato's ancient school founded in the grove of Akademos, the Academy became a place for scientific discussion and social debate. Inspired by the ancient tradition, the development of the Academy can also be linked to Athenian democracy. As a place where participatory democracy evolved, the Athenian agora can be an inspiration for the creation of a contemporary digital agora (Olszewski & Wendland, 2021) which facilitates the participatory shaping of space through the use of modern geo-information technologies. The university campuses adhering to the tradition of the first Academy remain the heart of today's emerging so-called smart cities (Manville et al., 2014). At the same time, a modern campus can act as an urban living lab and provide a space for testing innovative technological and social solutions on a university scale before their implementation in large urban areas.

One of the key issues in the participatory shaping of development visions, both of smart cities and university campuses, is the problem of the local community's low involvement. This phenomenon has a high frequency of occurrence specifically in Eastern Europe as a consequence of long periods of passivity and lack of trust in institutions, which is typical for post-communist countries. One of the most effective ways of social activation, which is a prerequisite for shaping deliberative democracy at the local level and creating an open society (Popper, 1966), is the use of gamification methodologies and modern geo-information technologies. This approach may be implemented, for instance, through the development of so-called serious games (Abt, 1970; Djaouti et al., 2011; Duke, 1974), which provide users with the opportunity to entertain themselves, ensuring the transfer of attractively administered knowledge and players' activation. One development of this approach is the so-called geogames (Ahlqvist & Schlieder, 2018; Andrade et al., 2020; Poplin et al., 2017, 2020). These types of games are a combination of geospatial technologies, serious game methodologies, and participatory engagement of the local community. This provides city authorities and urban planners with the tools to engage a wide range of stakeholders, conduct a simulation analysis of multiple alternative scenarios, and increase the level of public involvement.

Skilful social activation facilitates the use of a mechanism referred to in the literature as volunteered geographic information (Goodchild, 2007; Haklay, 2010; Howe, 2006; Martella et al., 2015). Volunteered geographic information plays an important role in the approach proposed in this article. This concept, widely used, for example, in OpenStreetMap data collection, involves the social engagement of users in collecting, verifying the quality of, and updating spatially located data. Crowdsourcing develops under the influence of geo-information technologies and is an effective way to solve problems and create information by grouping participants (e.g., serious geogame users) around a collective idea. Initiatives like that shape (geo)informative

society as well. Serious geogames can be used in various fields such as smart city development, public transportation, energy efficiency, or climate change impacts (Olszewski & Wieszaczewska, 2016). The authors of this article developed and evaluated a serious geogame called Campus Changer to activate the academic community of the Warsaw University of Technology (WUT) and plan the participatory development of the university campus as a living lab of the capital city of Warsaw. In 2026, the WUT will celebrate its 200th anniversary. This milestone provides an opportunity to honour the legacy of Poland's best technical university while modernizing its campus. The revitalization of the campus requires engaging the academic community to propose changes in the spirit of participatory democracy, ensuring these changes will result from joint efforts. The use of gamification methodology in the developed serious geogame will promote social (geo)participation and facilitate the campus co-creation process.

The aim of the authors of the article is to develop the geogame Campus Changer, which allows the use of location-based game capabilities and detailed geospatial data (3D model of the WUT campus) as a powerful geoparticipation tool. In combination with GIS tools, this game also enables spatial data mining analyses useful in spatial planning.

The aim of the research is not only to develop a serious geogame, but also to analyze the possibilities of using this solution as a tool for social geoparticipation—both on the scale of the university campus and the entire city.

Specifically, we aimed to investigate whether such a tool can broaden community engagement, generate diverse proposals for spatial interventions, and provide structured input for campus development. To address these goals, the project combined a digital gameplay environment with the collection of participants' decisions, socio-demographic data, and qualitative feedback. The evaluation was carried out through the analysis of gameplay data using GIS methods and the integration of user opinions on selected campus areas. The results inform both the methodological value of serious geogames and the substantive vision for campus transformation.

2. Literature Review and Examples of Geogames

2.1. Serious Games

The key factor in the sustainable development and shaping of so-called smart cities by their residents is the ability to harvest and process available information (including spatial data), as well as the needs and expectations of the local community, and to extract and use the knowledge obtained. At the same time, this process supports the creation and development of an open (geo)information society. One of the most effective ways to implement this process is the use of gamification techniques and so-called serious games (Alfrink, 2014; Kapp, 2012; McGonigal, 2011; Uskov & Sekar, 2015; Zichermann, 2013).

Entertainment is not the only objective of creating serious games, although their entertainment potential is crucial as it influences motivation and involvement (Białous, 2024). The overriding objectives of serious games are to educate, train, simulate, and solve social problems. The intention of serious games is for players to acquire, develop, and consolidate specific skills and solve problems. They can also be used to raise awareness of the role of social responsibility and the consequences of taking economic and social action in the process

of shaping and using space. Serious games can contain elements of gamification, support active learning, and simulate real-life environments (Figure 1). Additionally, they can be a tool for provoking a measurable reaction or change in the player. Interactive games which integrate geographical data and GPS technologies or use real spatial data and geodesic systems for collecting information about space fit into the category of serious games as geogames. The terms location-based game, location-enabled game, and geolocation-based game also appear in the literature (Alavesa et al., 2017; Groundspeak, 2000; Montola et al., 2009; Pacmanhattan, 2004; Paelke et al., 2008).

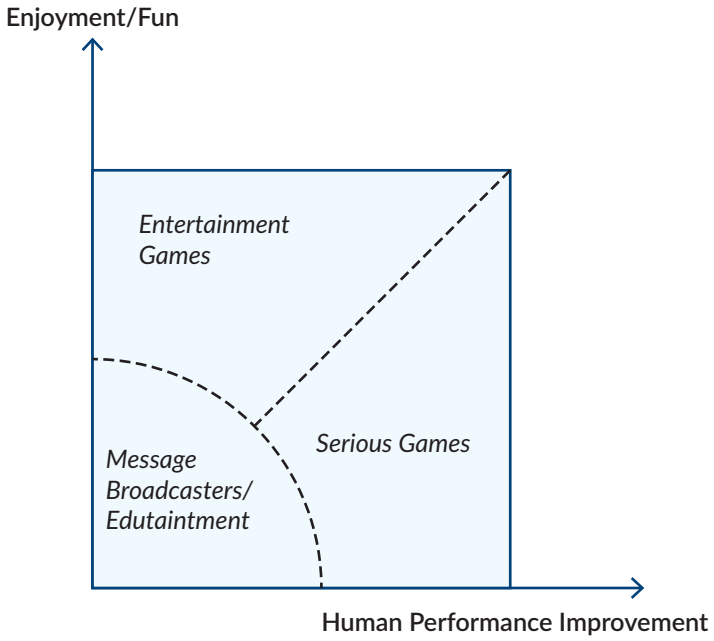

Figure 1. Differences among entertainment games, message broadcasters, and serious games. Source: Loh et al. (2015).

Computer games have been developed since the mid-20th century and have since then become part of mass culture. Electronic games are not only one of the main application areas of ICT but are also used in entertainment and education. Digital serious games can also be utilized in environmental protection, treatment, and rehabilitation, business development, etc. (Arnab et al., 2015; Breuer & Bente, 2010; Carvalho, 2017). Another application of such games is the visualization of spatial data, urban planning, or the optimization of urban transport (Canossa et al., 2013; Carvalho et al., 2015; Mat, 2014; Olszewski et al., 2018). With technological developments in geoinformation extraction and processing, computer games succeed in the increasing use of spatial data. Some of the earliest examples of this type of game were Ingress and Pokémon GO. However, it should be emphasized that these games were played on a map and not in a 3D urban space. The use of spatial data in serious geogames now demands a much higher level of detail and precision (LoD). A major impetus for the development of games that fully exploit the possibilities of 3D space models has been the use of game engines such as Unity or Unreal for the development of in-flight simulators. The 2020 edition of Flight Simulator, for example, uses around two petabytes of Bing map data, including aerial photographs and 3D scans.

2.2. Gamification in Social Participation

Social participation has long been seen as an essential element of democracy, ensuring that the public can affect the decisions of local authorities and public institutions. Traditional forms of consultation, such as open meetings, surveys, or referenda, do not always attract a wide range of stakeholders. For this reason, new tools are increasingly being used to encourage active participation. Gamification can effectively enhance the motivation of participants as it introduces an element of fun, challenge, and immediate feedback (Hamari et al., 2014). As a result, those taking part in consultations experience greater engagement and satisfaction with participation.

Recent years have seen a growing interest in the use of gamification mechanisms in various areas of social life, including civic participation processes. Gamification, defined as the use of game elements (e.g., scoring, levels, rewards) in non-game contexts, is gaining popularity in the areas of urban planning, education, and social consultation (Deterding et al., 2011). The core objective of these activities is to increase the engagement of different groups in decision-making and sensitivity to social issues.

As a tool for social participation in spatial design, digital games support the development of a participatory culture in which citizens are actively involved in the planning and implementation of local spatial policy. This is exemplified by the game Minecraft, which is used in initiatives such as Block By Block to strengthen relationships in the community and revitalize neglected public spaces. The game serves as a collaborative platform and visualization tool to engage local communities in spatial policymaking. On the other hand, Cities: Skylines, as a city simulation, can be used to elicit ideas from residents in the spatial planning process, as shown by the example of the city of Hämeenlinna in Finland. One can also see the potential of games to diffuse causality, facilitating participation in the creation of spatial policy in the comfort of your home, which was particularly important in the era of the Covid-19 pandemic (Szot, 2021).

Gamification mechanisms in social participation can be divided into several main categories. Firstly, a system of points, badges, and rankings helps to clearly visualize participants' progress (Zeng et al., 2017). Secondly, narrative elements, such as a storyline or a guiding character, help to build an emotional connection with the project. Thirdly, collaboration or competition between participants plays an important role, which can increase commitment and encourage more frequent interaction with the system (Table 1).

Table 1. Categories of gamification mechanisms.

Category of gamification mechanism	Subcategory	Features	Examples of use
Reward systems	Points	Rewards for the completion of specific actions, progress monitoring possible	Points for voting in public consultations Rewards for activity on the platform
	Badges (rewards)	Distinction for specific achievements, building internal motivation	Xyz badge for the participation in numerous initiatives Medals for long-term commitment
	Rankings	Facilitating the comparison of participants' achievements, stimulating competition	List of the most committed participants Ranking of groups or districts in the civic budget

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Narrative elements	Storyline	Creation of narrative context that emotionally involves participants	Story about the impact of civic decisions on urban development Simulation of consequences of various actions
	A guiding character	A character helping the user to get around the system	A virtual assistant explaining the decision-making process A hero guiding the user through the stages
Type of interaction between users	Collaboration	Engaging the users in collaborative project work	Creation of teams to implement public initiatives A system of common objectives to achieve
	Competition	Stimulating the activity through competition between the users	Competition for the best idea for public space development Challenges with rewards for the most active users

2.3. Examples of Games

Contemporary geogames are increasingly going beyond traditional educational and entertainment frameworks to become innovative tools supporting participatory urban design processes, especially in academic environments. Examples such as NextCampus or EquiCity Game (Nourian et al., 2023) show how games can simulate complex spatial decisions, engage different stakeholders, and present the consequences of alternative development scenarios. Initiatives such as Participatory Chinatown or Community PlanIt in turn focus on activating the residents and incorporating their voice into the planning process through gamification mechanisms as part of public consultations.

Geogames also adopt a form of spatial experiment, both physical, like Stroll Around Yesterday, and digital, like E-polis (Gazis & Katsiri, 2024) or Cities: Skylines – Campus, for example, allowing the participants to experience, test, and design space under simulated conditions. Their common denominator is the use of the game medium to increase engagement in real processes of shaping both urban and academic spaces.

Platforms such as Neighborland, Play the City, and Games for Cities operate on a different plane. Although they do not integrate advanced spatial data or GIS analyses, they are crucial in building the model of open inclusive participation. Neighborland allows the residents to submit ideas and run consultations through a user-friendly form of online communication. Play the City (2025) supports creative urban experiments based on cooperation between professionals and local communities, while Games for Cities uses gamification mechanisms to increase involvement in sustainable urban development. They have a common objective: the democratization of spatial planning and supporting the co-creation of a city as the common good.

Platforms such as Second Life can also be treated as both a tool and a universe for creating geogames. Second Life is a multiplayer virtual world that allows cooperating with other players in a virtual, 3D world. Developed for personal computers in 2003, in 2013 it had approximately one million regular users. The Second Life platform was used in education (universities create virtual campuses for lectures and seminars), art and creativity (artists and creators design immersive art installations and virtual galleries), research and experimentation, recreation and role-playing, and therapy and support groups.

The above examples greatly illustrate the potential of gamification in the broad activation of the participants and in building an inclusive decision-making environment. The immediate visualization of the consequences of decisions increases motivation and makes the voice of each participant visible in real time. Research shows that this type of interaction can enhance trust between stakeholders, as well as an understanding of the complexity of planning processes (Gordon & Walter, 2019; Hassan & Hamari, 2020).

On the other hand, achieving a high level of realism, by using LoD 3 or LoD 4 in building modelling, among other things, is time-consuming and requires substantial funding. Not all social groups have equal access to equipment and digital skills, which raises questions about digital exclusion (Faure et al., 2020). There is also a risk of part of players making decisions to merely score points or win a position in the ranking. For this reason, game designers must ensure transparent and substantive foundations of the process.

Gamification in public participation is a promising tool for increasing civic involvement and allowing the public to actively influence the decision-making process. Mechanisms like narratives, immediate visualization of changes, and complex analytical tools (GIS) considerably enhance the appeal of the entire process.

It should be emphasized that digital platforms enabling social geocivic participation are a special case of geogames. Solutions of this type can be considered not only as geogames, but also as serious games supporting social debate on the functioning of the city and its development. Digital platforms such as Participatory Chinatown, Better Reykjavik, or Community PlanIt involve interactive exploration, decision-making, and immediate visual feedback on player actions. These digital platforms show that gamification may find application in diverse social and urban contexts. With the growing popularity of immersive technologies (AR, VR) and tools for data analysis (GIS), one can expect even more advanced and engaging solutions supporting participation and collaborative decision-making.

Video games, in general, rely on players' engagement emerging spontaneously from the sheer opportunity to do something. While a player's acceptance of the game premise is a prerequisite for engaging with the game at all, once the player does engage, they tend to stay within the game even in the absence of an explicit prompt to act (Gee, 2007). This is most starkly evidenced by "walking simulator" games, where, in the most

extreme cases, the player is offered no explicit objectives and no corresponding explicit challenges (e.g., Key & Kanaga, 2013; The Fullbright Company, 2013). Arguably, it is more appropriate to discuss gameplay in terms of prompts or invitations rather than challenges, since demonstrating that a video game can maintain player engagement at least temporarily, without imposing any sort of difficulty, would be trivializing.

3. Problems and Methodology

3.1. WUT Campus and Its Problems

The WUT is one of the best technical universities in Poland, with almost 200 years of tradition and history. The university conducts advanced research in nearly all technical disciplines. For several years, WUT has also been one of the 10 research universities in Poland, which further stimulates its scientific development. However, the problem with the university is the low degree of interdisciplinarity in research and courses offered. The alienation of the individual faculties can also be seen in the physical space—even the area of the main campus is an unintegrated space dominated by car traffic and car parks. It needs to provide a sense of community of urban space and ideas. Despite its central location and historical significance, the WUT campus faces several challenges that hinder its functionality, accessibility, and integration with the surrounding urban environment. One of the primary issues is multi-level alienation, evident both in the spatial fragmentation of faculties and the lack of cohesion between the campus and the urban fabric. The area remains largely closed to the city, limiting its accessibility and interaction with the surrounding community. Additionally, the campus is predominantly car-centred, with excessive parking spaces and vehicles often occupying pedestrian zones, making mobility difficult, particularly for individuals with disabilities. The built environment is characterized by an overabundance of concrete surfaces, a lack of green recreational spaces, and a general absence of sustainable and pro-environmental design solutions. Despite the presence of distinctive architectural elements, such as historic buildings from the late 19th century and a protected natural monument, parts of the campus remain degraded and underutilized (Figure 2). The planned revitalization seeks to transform the campus into a model university space—one that is multifunctional, aesthetically cohesive, ecologically sustainable, and inclusive. Key objectives include improving accessibility, integrating green infrastructure that aligns with climate adaptation strategies, and reinforcing the campus's historical identity while positioning it as a modern, competitive academic centre.

Figure 2. Public spaces of the main campus of WUT.

3.2. The Game Concept and Gameplay Walkthrough

Campus Changer is a proprietary geogame designed and developed in the Unity engine and using accurate models of the WUT campus (LoD 3; Główny Urząd Geodezji i Kartografii, n.d.). The game allows the users of the game to explore the virtual space of the campus and suggest changes in its organization and appearance. The participant is guided by Genius Loci, who is the university's protective spirit, adding a narrative character and enhancing the sense of mission.

Campus Changer was designed not primarily for entertainment but to engage the academic community in participatory planning, stimulate reflection, and collect spatially explicit feedback. This geogame can also be treated as a digital platform enabling social geoparticipation. The use of GIS tools to analyze the collected data of game users also allows for the full utilization of the possibilities offered by spatial data mining in the decision-making process.

Decisions made by players have an immediate effect on the appearance of the virtual campus, which acts as a powerful incentive. Moreover, various stakeholder groups participate in this process, including academic staff, students, and residents of the nearby area. This facilitates understanding different perspectives and real co-creation of the campus space. Additionally, a geoinformation tool devised by the authors allows for the conversion of data about decisions made by users into gjson format, which is subsequently analyzed in GIS systems. This promotes drawing conclusions about the preferences of different groups within the academic community and planning specific urban solutions.

In comparison with traditional consultations, the Campus Changer geogame generated a wide range of opinions and ideas, including from groups frequently overlooked in participatory processes. Immediate visualisation of decision consequences, combined with narratives and elements of challenge, made participants feel responsible for shaping the common space.

Examples of changes anticipated by the participants of the game are shown in Figure 3. The left side depicts the current state, while the right side shows the target state. For instance, an outdoor gallery is expected in the square in front of one of the buildings. Players would like to see more greenery and benches around the fountain. A good example of the proposed changes is also the expected relocation of the rubbish bins to provide space for a café.

During the preliminary analyses, a series of site visits were conducted. Nine spots within the campus, which in the research team's opinion required changes in the spatial development the most, were identified. They included (Figure 4):

1. The area around the chimney and the road leading next to the Mechanics Building;
2. The square between the Faculty of Building Services, Hydro and Environmental Engineering, and the Mechanics Building;
3. The gates and inner courtyards of the Chemistry Building;
4. The area between the Faculty of Mathematics and Data Science and the Chemical Technology Building;
5. The fountain and the area surrounding it in front of the Physics Building;
6. The green space between the Physics Building and the residential building;

Figure 3. A current view (left) and an option of designed changes (right).

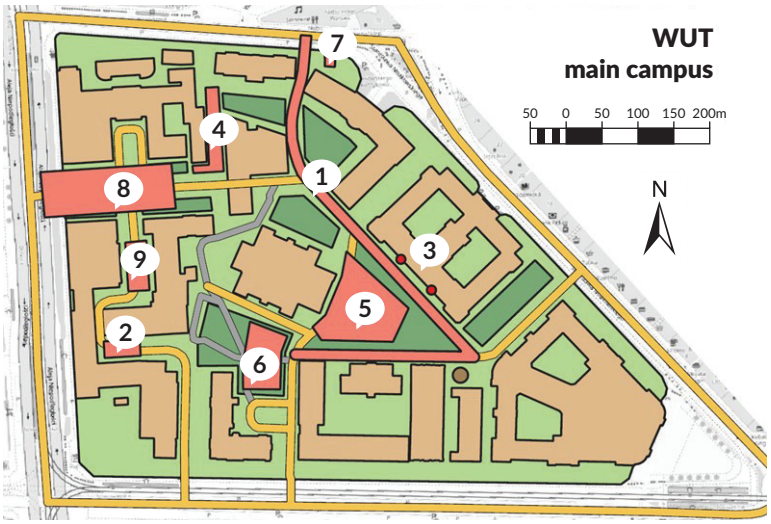

Figure 4. Location of selected areas.

7. The areas around the guardhouse at Koszykowa Street;
8. The area near the monument of Ignacy Mościcki;
9. The area between the Faculty of Electrical Engineering and the Institute of Aeronautics and Applied Mechanics.

A typical gameplay session in Campus Changer begins with the player entering the 3D model of the WUT main campus. Guided by Genius Loci, the guardian spirit of the university, the player is introduced to the objectives of the game and to the interactive characters representing different stakeholder groups (students, staff, residents). The player can freely navigate the campus, approach specific locations, and interact with these characters, who present diverse perspectives and challenges related to the use of campus spaces. At each of the nine selected areas, the player is asked to consider options for change—such as reducing parking to increase green areas, revitalizing a fountain, or adding social and cultural facilities—and to choose solutions. These decisions are immediately visualized in the 3D environment, allowing the player to see the transformation of the campus in real time.

The gameplay continues as the player explores additional areas, interacts with further characters, and gradually shapes a holistic vision of the campus. At the end of the session, the system records the player's decisions together with basic profile data, which are then analyzed using GIS tools and combined with feedback to inform the participatory planning process.

3.3. Game Design

The game design for Campus Changer had three main goals:

1. Maintain the user's engagement for longer than it takes to fill out a questionnaire, allowing us to collect more answers from each user;
2. Provide more detailed context for questions;
3. Present each question as a discussion between stakeholders, as opposed to relying solely on the user's pre-existing point of view.

While the Campus Changer platform is implemented as a PC-based serious game, it integrates a highly detailed 3D model of the real campus and engages players with spatially explicit decision-making tied to real locations. This duality—between a virtual gameplay environment and its grounding in real-world geography— allows Campus Changer to be treated as both a geogame and a serious game.

In Campus Changer, the first interaction between the user and the game is the initial conversation with Genius Loci, a fictional character. Superficially, this introduces a simple narrative, but functionally this is how we communicate to the player that characters in the game can be approached and talked to. The user is thus aware that any person they can see in the game represents a potential interaction, and seeing a character in the distance becomes a gameplay prompt. The player is free to ignore the prompts, but since they have already engaged with one, they are more likely to continue engaging. This would not necessarily be the case if prompts were not readily available and clearly presented to the user, for instance if questions were triggered by simply entering an otherwise unmarked area.

It would be incorrect to assume the user engages with the game in one specific way. Currently accepted understanding is that the same in-game events can be interpreted in widely different ways by different players, depending on each player's unique emotional needs and preferences (Hunicke et al., 2004). Video games leverage this by providing several parallel streams of stimuli. A simple example is a game where an arcade challenge such as performing an increasingly difficult series of timed jumps is accompanied by a story about searching for a kidnapped princess, which in turn is stacked on top of memorable visuals and music (Nintendo, 1985). In Campus Changer, the interaction can be seen as a series of tasks dispensed by Genius Loci, or even a series of debates between other characters, providing an alternative engagement method compared to the exploration of the campus. This approach is not because the creators believe they have crafted a great story or characters, but because some users find it easier to engage with the characters, while others prefer interacting with the in-game environment.

We hypothesize that this is a unique advantage of a (serious) game over a traditional survey, which only engages the user in a singular manner, and does not leave much room for customizing the experience. For instance, it is equally natural for the user to traverse the campus along any available path, whereas a simple body of text, such as a survey, implies just a single, linear way to read it, typically from top to bottom.

Responding to questions when "standing" in a corresponding spot within the virtual representation of the campus also means that a wider range of information is available to the user:

- They can examine the local spatial relationships.
- They can familiarize themselves with the overall function of the surroundings.
- They can more easily envision themselves using a given space.
- If they are already familiar with the campus, it is easier for them to recall specific memories and associations.

We decided to present questions as discussions between characters in order to further ground the interaction in reality. The university campus presented in the game is not an abstract or fictional place but can be and is actually visited by thousands of people on a daily basis. It has, in other words, its stakeholders. We distilled a number of plausible responses to our questions into a number of fictional personas that represent archetypes of campus users, such as a student, a teacher, an administrative employee, or a resident (since this particular campus also contains residential buildings). This is meant to help overcome the main disadvantage of a PC app, which is the absence of other users.

Some design objectives were pursued by omission. Campus Changer provides no method for keeping a score and no negative consequences for user decisions. For example, a character who represents a certain opinion will not express anger if the user chooses differently. The goal here was to discourage users from optimizing their experience according to an external metric. Anything that could be interpreted as a measure of success could lead users to modify their answers to fit the expectations of an implied judge.

4. Preparation and Testing of the Game

4.1. Development of the Game

The main goal of the application is to implement an innovative way of collecting the university community's opinions on the revitalization of the WUT campus. The necessary information is divided into two categories: the vision of the new campus and user data (so-called metrics). Information about the campus vision is gathered during the gameplay as the player completes tasks. User data are harvested at the beginning of the game, gathered almost imperceptibly for the user, as the collection is integrated into the game tutorial. This knowledge allows the authors and project teams to draw conclusions about which revitalization plan should be adopted.

The last part of the game design stage for Campus Changer was planning the structure of the application code. Productions based on the Unity engine are divided into scenes, where each scene contains a hierarchy of objects that fill it.

It was predicted that each of the planned functions of the application would require at least a few objects with individual classes overseeing their operation for implementation. For this reason, a structure based on "managers," which are objects that steer the operation of their subordinate subcontractor objects, was decided upon. Each "manager" is supposed to directly exchange data with the engine and send fragments of this information to specific "executor" objects when needed. Such a project structure allows for maintaining a high level of transparency in the application operation and facilitates the debugging process since an error in one section of the application does not affect the operation of another part.

Accurate representation of the main campus of the WUT as a 3D model with an adequate level of spatial information generalization and cartographic quality required obtaining 3D data of the buildings located in this area. Initially, it was planned to acquire the required models using the website geoportal.gov.pl, which provides a 3D representation of buildings from the BDOT10k database. However, the idea was abandoned. The decision was made due to the insufficient detail of the model visualizations and the way this information was recorded. Ultimately, the utilized 3D models of buildings were those designed as part of the project Warsaw University of Technology Ambassador of Innovation for Accessibility. The source data underwent an aggregation process, which facilitated the creation of models consisting of several larger fragments, enabling Unity to render them much more efficiently. Additionally, each object in the game world was required to have a designated collision with other objects. As part of the game project implementation, simplified representations of each obtained model were created to be used in the collision physics generation process.

The prepared data were exported to the .fbx format and imported into the Unity environment, where their integrity was later checked.

4.2. Technical Implementation and Testing of the Game

The authors intended the final version of the game Campus Changer to operate at an efficiency of around 60 frames per second for an NVIDIA GeForce GTX 1650 graphics card, Intel Core i7 ninth-generation processor, and 32 GB of RAM. During the project implementation, a series of prototypes were tested to

analyze the system performance. The game mechanics facilitate movement around the scene with the WASD keys and "looking around" using the mouse. Subsequent iterations of the game prototype focused on optimizing the method of generating objects and scene lighting.

The optimization process involved, among others, adjusting numerous variables in the engine regarding:

- The quality of the generated light and shadows;
- The compression of used textures and generated materials;
- The distance of shadow generation from the player;
- The distance of object generation from the player.

Additionally, for materials such as leaves and tree trunks, which were abundant in the scene, the GPU Instancing option was enabled. This option made objects covered with such prepared material be instantiated directly by the graphics card, bypassing calculations at the computer processor level. Furthermore, for all objects, the Occlusion Culling option was enabled, ensuring that objects the player does not view in a given frame are not generated. Subsequently, for vegetation models (tall and low greenery), the LoD Group function was added, which replaces models with less detailed ones when the player is sufficiently far away, significantly reducing the workload of the graphics card by eliminating unnecessary geometry calculations.

In most cases, such an optimized prototype allows for obtaining 60 frames per second with the mentioned equipment specification, with instances of reduction to 30 frames per second in spots in the scene most "cluttered" with objects.

The final version of the game was prepared both in Polish and English.

4.3. Evaluation Process

Information about the consultations on the campus revitalization project for the 200th anniversary of the WUT was sent to the entire academic community of the university. An email encouraging recipients to download the game and participate in the gameplay was also sent to community members: staff, doctoral students, and students. Due to the high hardware requirements, the 2.4 GB installation file was downloaded by only a portion of the respondents. A total of 92 participants, representing staff, doctoral students, and students at the WUT, took part in the Campus Changer game.

The game was tested for three different equipment specifications:

- Weaker than that for which the app was created;
- Similar to that for which the app was created;
- Stronger than that for which the app was created.

Each of the three machines used for testing operated using a Windows 10 system. The application launched in all cases, but the performance varied. On the weakest computer, the game ran at an average of 30 frames per second, with drops to 15 frames per second during more demanding moments. Tests on hardware with

computational power similar to that of the developer's computer yielded results of around 60 frames per second in most cases, with drops to 30 frames in demanding situations. The strongest configuration achieved a consistent result of 60 frames per second, with occasional drops to 50 frames per second.

During test gameplay, several minor bugs were found, such as materials and objects mismatched (incorrect texture), objects mispositioned on the scene, or text extending beyond the designed UI. However, a more serious issue was also discovered. The detected problem was that after exiting the game and rejoining it, there was an unplanned reset of already completed tasks. This bug was fixed before preparing the final version of the application.

As soon as the tests were complete, the preparation of the final version of Campus Changer began through the implementation of indispensable corrections. The game was prepared in two versions: Polish and English (see Figure 5 for the English version).

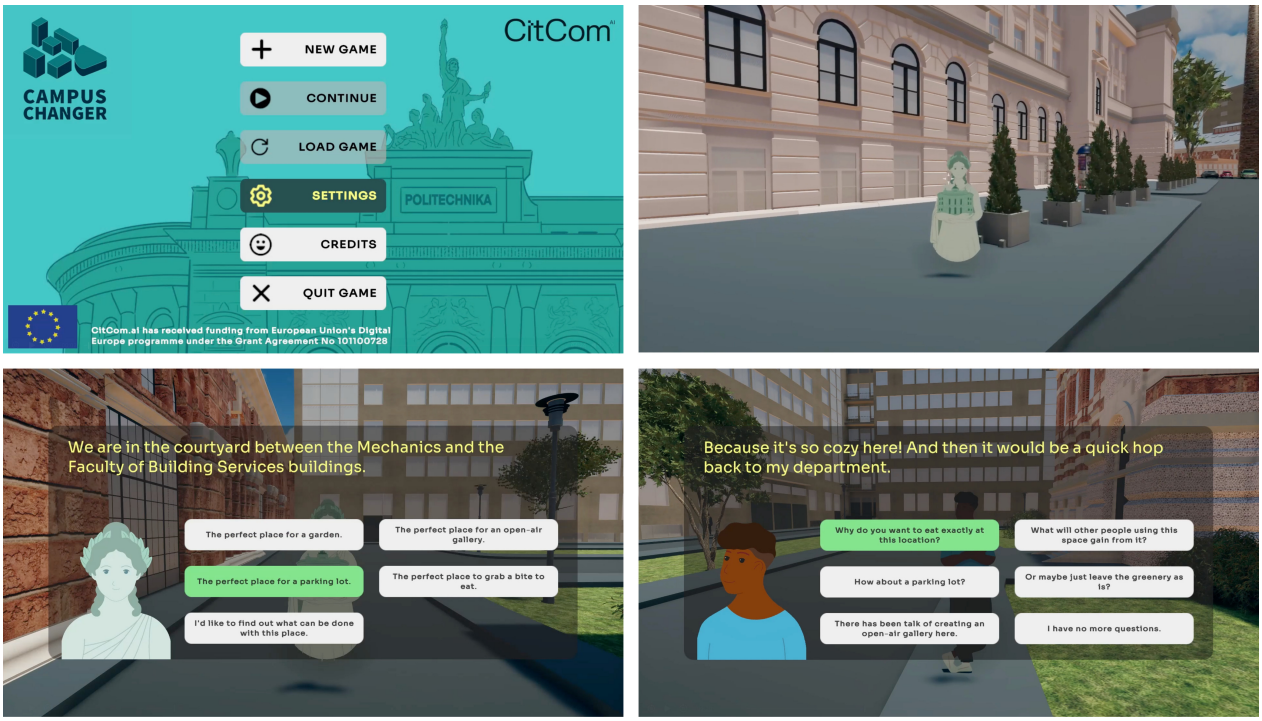

Figure 5. Dialogues in Campus Changer.

5. Results and Discussion

To analyze the results obtained through the use of the Campus Changer serious game, a proprietary geoinformatics tool was utilized. This tool facilitates the conversion of data stored on the Unity server in gjson format into a spatial database. This allowed for the automation of the data analysis process in a spatial context using GIS tools. Table 2 contains a summary of the tasks completed by the players and the dominant responses received. The results indicate that players, who are representatives of the university's academic community, would welcome changes in the way the campus space is utilized. The expected changes include a significant expansion of green areas and pavements used by pedestrians and bicycles at the expense of

reducing parking spaces. This concept, expressed as "human-oriented," reflects the idea of universal design and Society 5.0.

The analysis focused on nine selected areas of the campus identified as requiring revitalization or a change of use. Within the serious geogame, participants interacted with these areas, and the data generated by the game engine were automatically transformed into gjson and stored in a spatial relational database. This enabled us to conduct classical GIS spatial analyses and to visualize players' activities and trajectories on the campus map.

In addition to the spatial data, we collected user profiles and participants' opinions concerning each of the nine areas. These qualitative inputs were integrated with the spatial analysis results, which allowed us to interpret preferences and needs expressed during the game. The combination of both data sources provided the basis for developing a holistic revitalization concept for the campus, aligned with the expectations of the academic community.

Analysis of results also shows that the academic community expects the creation of food and drink spots like cafes with outdoor tables and folding chairs, aiming not only to quench your thirst and satisfy your hunger but also to help create an open community and support networking. The need to meet more than just physiological needs is exemplified by the desire to establish an outdoor gallery to present artwork as interactive multimedia exhibitions. It is also interesting that there is a proposal for mobile catering in the form of food trucks to be available in the central WUT campus. The area selected for food trucks is chosen so that these vehicles would not create any major disturbance for pedestrian or cyclist traffic.

The users of the game expect the revitalization of a heritage fountain, which is one of the oldest spots on the university campus, dating back to almost 200 years ago. This structure and the surrounding area are associated with historic events from World War II, especially the Warsaw Rising in 1944. The results of the serious game show that the academic community respects its history and expects the heritage site to be restored and surrounded by greenery rather than be replaced with a stage for outdoor performers or a car park.

Table 2. Most frequent responses from the players.

Problematic location	Location on the campus (map)	Most frequently proposed solution	Other solutions
The area around the chimney and the road leading next to the Mechanics Building		Widening the pavement at the expense of the road and the car park	Widening the road and enlarging the car park
The square between the Faculty of Building Services, Hydro and Environmental Engineering, and the Mechanics Building		Creation of an outdoor gallery allowing for interactive visualizations of artwork	Car park Food and drink facility

Table 2. (Cont.) Most frequent responses from the players.

Problematic location	Location on the campus (map)	Most frequently proposed solution	Other solutions
The gates and inner courtyards of the Chemistry Building		Opening the building's courtyard for the academic community	Closing the courtyard Limiting access to the courtyard
The area between the Faculty of Mathematics and Data Science and the Chemical Technology Building		Modern decorative exterior design	Enlargement of the car park Green area
The fountain and the area surrounding it in front of the Physics Building		Restoration of the heritage fountain and extension of the surrounding green area	A stage for outdoor performance
The green space between the Physics Building and the residential building		Cafe with outdoor tables	Bin shelter
The areas around the guardhouse at Koszykowa Street		Food and drink spot with outdoor tables	Security guard shelter Living Lab
The area near the monument of Ignacy Mościcki		Green area	Car park
The area between the Faculty of Electrical Engineering and the Institute of Aeronautics and Applied Mechanics		Food truck area	Utility facility for the building

6. Conclusions and Future Work

The preparation of Campus Changer required great effort and dedication associated with both the preparation of the game concept and the creation of detailed 3D models of the buildings, the design of the graphics of the game, and the optimization of functionality in the Unity engine. Effective communication with the academic community of the WUT and convincing them to participate in the serious geogame was another formidable challenge. Due to quite high equipment requirements, both in terms of the graphics card, the processor, RAM, and disk memory, approximately 100 people took part in the tests of the Campus Changer game. The number is equivalent to the number of participants in consultations on the WUT campus revitalization in 2024. The consultations were conducted by the university's authorities utilizing traditional methods. Participation in the game allows the players to familiarize themselves with the WUT campus by taking a virtual walk around a 3D model of the university. An indirect manner of learning about the campus is a value in itself, but the use of a geogame as an effective tool for public geoparticipation is equally crucial.

The conducted research shows that the serious geogame is an extremely effective tool for conducting social consultations and stimulating the activity of the academic community. It is also an attempt at the modern implementation of the idea of the digital agora by utilizing mechanisms of a serious geogame. The emotional involvement of the players proved to be much higher than during surveys, interviews, and consultations. The most engaging element of the game was the introduction of Genius Loci into the game. The guardian spirit of the university guided the participants of the serious game, facilitated learning about the virtual campus, and, first and foremost, guided and supported the users during decision-making. It was also justified to introduce avatars of other characters into the game, including employees, students, or residents of nearby houses. While talking to these characters, the players had an opportunity to familiarize themselves with different perspectives and needs. Users' opinions show that student-players considered virtual conversations with characters representing both academic and non-academic university staff to be of highly cognitive value. This was an opportunity to learn their views and better understand them. The result is the creation of commonality in the academic community and the realization of the idea of deliberative democracy. As noted by Nicholson (2012) and Kapp (2012), the effectiveness of gamification in the context of public participation depends not only on the introduced scoring mechanisms or rankings. The significance of social context and values that guide the whole process is key. In urban development or university campus projects, it is important to address the needs of different groups and to communicate objectives transparently. Introducing gamification mechanisms for the sole purpose of "fun" could trivialize the problem if participants lack a sense of real impact on reality.

The development of an in-house tool to automatically convert the decisions made by players in the virtual world of Campus Changer into a spatial database also plays a crucial role in the use of the serious geogame. The conversion and analysis of the data in the GIS tool environment allow for discourse on space development and revitalization of the WUT campus, not in the virtual world of the game but in the real-life space of the university campus. The obtained results will facilitate a more thorough debate on the changes in the way the university operates on the eve of its 200th anniversary.

The developed game is dedicated to the revitalization of the main campus of the WUT, but it can be altered to suit a different area. It is important to highlight that the concept of the game is universal since it can be adapted with relative ease for use in another public space, such as the campus of any university or city district.

The developed source code in the Unity game engine is generic in nature, although of course adapting the game for another area would require developing 3D models of that space and adjusting the narrative. One of the concepts of the planned development of the Campus Changer geogame is also to increase the level of player interaction. Engagement in a more heated debate or interaction with virtual characters in the game world could result in greater involvement and a better understanding of various attitudes. Another intriguing idea for the development of the game is to allow players to enter the buildings and explore them virtually. This version of the game could also be used to learn about the university by potential visitors at WUT or high school students planning to study at the university.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The data collected during the research are available upon request by email. The installation file of the Campus Changer game can be downloaded from the site: https://drive.cenagis.edu.pl/s/CampusChanger

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

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