# Integrating Analog Games and Minecraft for Urban Greening Education: A Serious Game Approach for Elementary Students

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Abstract: This study presents the development of a serious game that integrates an analog board game with Minecraft to enhance urban greening education for elementary school students. Urban greening plays a crucial role in sustainable urban development by contributing to environmental regulation, public well-being, and achieving Sustainable Development Goals (SDGs). However, environmental education in Japanese elementary schools remains limited due to the complexity of the topic and curriculum constraints. The proposed game features intuitive controls and real-time simulation, allowing students to learn about urban greening through interactive city-building activities. The game system uses a web camera to capture the placement of physical game pieces on a board, with TensorFlow processing the image to identify piece types and positions. This data is converted into NumPy array, corresponding to Minecraft's world coordinates, and the city is constructed using pre-defined building information. A scoring system evaluates development levels and air pollution based on the types, quantities, and configurations of buildings. The game promotes collaborative problem-solving and active discussion among players, enhancing engagement with urban greening concepts. Future work involves refining the missions, scoring mechanisms, and conducting practical tests to evaluate the game's educational effectiveness in fostering sustainable urban learning.

## 1 INTRODUCTION

Urban greening has been widely acknowledged for its multifaceted and substantial contributions to urban environments. It is expected to play a critical role in alleviating the urban heat island effect, enhancing air quality through pollutant filtration, promoting psychological well-being, and fostering more liveable urban spaces by offering areas for recreation and relaxation (e.g. Islam et al., 2024; Makram et al., 2024; Yao et al., 2020). Moreover, urban greening serves as a crucial strategy for climate change mitigation and adaptation in cities, contributing to carbon sequestration and reducing energy consumption (Norton et al., 2015). The integration of green infrastructure in urban planning has also shown economic benefits, related environmental regulation and property values (Song et al., 2018). Thus, urban greening is not just an environmental initiative but a comprehensive solution for sustainable urban development.

The United Nations' 2030 Agenda for Sustainable Development comprises 17 Sustainable Development Goals (SDGs) that are to be achieved by 2030. Within this framework, Urban Greening hold a critical role at the local level by providing recreational services, contributing to bioclimatic regulation, and functioning as carbon sinks. Lorenzo-Sáez et al. (2021) pointed that green urban areas (GUAs) make direct contributions to three key SDGs: SDG 11 - Sustainable Cities and Communities, SDG 13 - Climate Action, and SDG 15 - Life on Land. Urban greening represents an important aspect of environmental education, integrating various disciplines such as plant sciences, urban planning, community development involving diverse stakeholders, and engineering-based problem-solving. Within the framework of education for SDGs, theme of urban greening provides substantial educational value by addressing critical environmental, social, and technical challenges, thereby fostering a



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comprehensive understanding of sustainable urban development.

Additionally, urban greening is a promising theme for STEAM education due to its strong ties to sustainability and the SDGs. STEAM education is an interdisciplinary teaching approach that integrates Science, Technology, Engineering, (Liberal) Arts, and Mathematics (Yakman, 2006). This holistic approach encourages students to connect diverse subjects, solve real-world problems creatively, and develop skills essential for the 21st century. Urban greening involves enhancing city environments through initiatives like planting trees, creating green roofs, or designing sustainable urban spaces.

However, environmental education in Japanese elementary schools is not adequately covered in the curriculum. In Japan, the National Land Afforestation Promotion Organization (2020) highlights that forest creation, which utilizes the functions of plants to foster improvements toward a sustainable environment, is closely aligned with the objectives of the Sustainable Development Goals (SDGs). However, it has been pointed out that Japan's national curriculum guidelines lack explicit references to environmental education. Instead, "environment" is merely presented as an illustrative theme that may be addressed during the "Period for Integrated Studies," indicating the limited emphasis placed on environmental education within the formal curriculum framework (National Land Afforestation Promotion Organization, 2022). There are some practical examples of "green curtains" and "school greening" centered around elementary schools, but not all of them are positioned within educational activities (Zheng et al., 2020). As you can see, it is difficult to make greening a learning task for learners to take the initiative in Japanese elementary school education.

Urban greening education presents several inherent challenges from learners' engagement and motivational perspectives. First, the complex interplay between natural phenomena and societal factors makes it impractical to conduct empirical experiments or demonstrate immediate effects within the constraints of traditional classroom settings. Second, while observational learning from familiar urban environments in learners' neighborhoods and existing local data sets are valuable, the availability of suitable learning environments or relevant data cannot be consistently guaranteed across different educational contexts and communities where students live and study. While theoretical learning through idealized case studies is possible, such approaches may fail to establish meaningful connections with learners' lived experiences.

Gamification effectively addresses these pedagogical challenges by providing an interactive simulation environment where learners can observe the direct consequences of their decisions on environmental and social outcomes. Gamification has garnered significant scholarly attention across diverse disciplines, including education, informatics, human-computer interaction, and health sciences. While systematic reviews have shown mixed results regarding its educational effectiveness, numerous studies have investigated its potential for enhancing learner motivation and engagement (Seaborn & Fels, 2015; Koivisto & Hamari, 2019). Furthermore, the integration of collaborative elements in game design is expected to promote active discussion and peer learning, fostering the development of critical thinking and problem-solving competencies. These collaborative aspects are particularly pertinent given the multi-stakeholder nature of real-world urban planning and environmental management decisions.

This study aims to develop a serious game focused on greening activities for elementary school students, with the objective of fostering their understanding and increasing their engagement in environmental initiatives. A serious game is defined as a game designed with a primary purpose beyond mere entertainment, often serving educational, training, and professional development goals across various fields (Boyle et al., 2016). By experiencing the complex structure and effects of urban greening through a game-based format, children are enabled to engage intuitively and actively in environmental learning through urban greening simulations. This paper presents the development concept and the system architecture underlying the serious game.

# 2 GAME SYSTEM

## 2.1 Concept

Our game system design is grounded in social constructivism (Vygotsky, 1978), which posits that knowledge construction occurs through dialogic interaction and social engagement. The system facilitates collaborative urban greening strategies through an approach, combining physical game board manipulation with digital feedback. The learning process will be structured through designed mission scenarios incorporating scaffolding and fading, where urban planning challenges will progressively increase in complexity from basic city development to advanced environmental management. These missions, supported by computer-mediated interactions, are planned to guide students from simple spatial arrangements to complex decision-making involving multiple stakeholders and environmental factors, enabling them to develop experiential understanding of urban greening principles. As students demonstrate mastery of basic concepts, the scaffolding will gradually fade, allowing for more autonomous problem-solving in complex scenarios.

The integration of analog and digital game elements in educational contexts has emerged as a promising approach for creating engaging learning environments. A primary advantage of this hybrid approach is the provision of immediate digital feedback in response to physical object manipulation. This methodology has demonstrated efficacy with younger learners (Sluis et al., 2004; Zuckerman et al., 2005). The representation of urban planning elements through tangible objects on the game board, coupled with digital feedback, is designed to enhance spatial cognition through object manipulation.

For older learners, the incorporation of physical objects offers distinct advantages in supporting social tasks and collaborative activities. The tangible interface creates a shared workspace that facilitates collaborative engagement, and participants can more readily observe and interact with each other's contributions compared to purely graphical representations on digital displays (Suzuki & Kato, 1995; Zuckerman et al., 2005).

Based on these theoretical and empirical foundations, our game integrates analog and digital elements to present urban greening challenges and promote collaborative problem-solving among players.

## 2.2 Game Design

The game was designed with the aim of ensuring intuitive operation. To achieve this, the development was based on an analog board game framework. Additionally, a visualization component using Minecraft, which aligns well with STEAM education for children, was integrated. Specifically, the gameplay proceeds as follows: players place physical pieces on a game board, with each piece representing elements such as green spaces, residential areas, factories, and hospitals. Based on the placement of these pieces, a city is generated within the Minecraft environment (Figure 1, 2).

Each piece is assigned scores representing development factors—such as population, production, and convenience—as well as air pollution levels. These scores are influenced not only by the number of pieces placed but also by their spatial arrangement. For example, placing residential areas near factories increases air pollution levels, but this effect can be mitigated by placing green spaces between them. Players engage in discussions as they position the pieces and adjust their placements after observing the outcomes. Through this interactive city-building simulation, players can learn about the effects of urban greening on environmental and urban development.

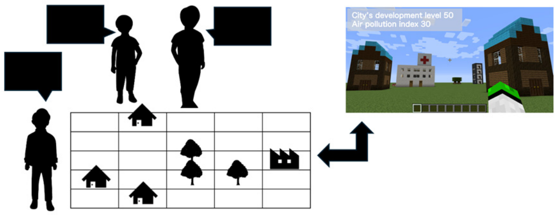


Figure 1: Concept Design.

Figure 2: Game Pieces.

This game is structured around discussions and missions, encouraging players to deepen their understanding of urban greening through simulation and dialogue. In real-world urban development, the involvement of numerous stakeholders often results in complex situations. Examples of missions and key objectives during gameplay are as follows: 1) Create a city with a specified population: Place multiple residential areas and factories to enhance the city's development level. 2) Reduce air pollution while maintaining the development level: Strategically place residential areas, factories, and green spaces to balance growth and environmental impact. 3) Improve the city's convenience: Maintain green spaces while adding facilities such as hospitals and residential buildings. Additionally, a cost is assigned to each piece, and the total number of pieces that players can place is limited by a budget, introducing a strategic dimension to the gameplay. The missions can be flexibly adjusted based on the players' skill levels, ensuring a more tailored and adaptive experience. Through these missions, players engage in collaborative problem-solving and gain valuable insights into the complexities and strategies involved in sustainable urban planning.

## 2.3 System Environment

The system is composed of the following components: a laptop PC, a web camera, Google Colaboratory, and physical game pieces. We utilize the Minecraft Forge API, which provides hooks into Minecraft, to transfer information between the physical placement of the game pieces captured by the web camera and the Minecraft world. Minecraft version 1.12 is used in this setup.

The program is developed using Python (v3.12) and JavaScript (ES5). For Python, the non-standard libraries Tensorflow (v2.17.1), NumPy (v1.26.4), and mcpi (v1.2.1) are employed to handle computations and interactions with the Minecraft interface.

## 2.4 System Overview

The system requires the following equipment for operation:1. A game board (150cm × 150cm blank), 2. Game pieces (5cm × 5cm × 5cm per piece), with the number and kinds of pieces determined by specific mission requirements, 3. One laptop computer (meeting or exceeding Minecraft's recommended system requirements), 4. A web camera (recommended: 2 megapixels or higher resolution), 5. Internet connectivity.

The system operates as follows (Figure 3). First, players place game pieces on the board. The pieces are cubic in shape, with their top surfaces painted in distinct colors to represent different types of buildings. Next, Google Colaboratory controls the web camera to capture an image of the board. The captured image is sent to Colaboratory as image data and processed using TensorFlow to estimate the types and positions of the pieces.

The estimated data is converted into a 300×300 NumPy array, where each element corresponds to the position and type of a game piece. This array directly maps to the x, z coordinates in the 300×300 block grid within the Minecraft world. The generated NumPy array data is then read by the Building Program and the Scoring Program on the laptop PC.

The Building Program uses the recorded types and positions of the pieces in the NumPy array to place corresponding blocks in the Minecraft world. It references a CSV file containing predefined information on the structures and block types for each building type. Subsequently, the Scoring Program calculates the city's development level and air pollution index based on the types, quantities, and arrangements of the buildings. These values are displayed in real time as an overlay on the Minecraft gameplay screen on the laptop PC.

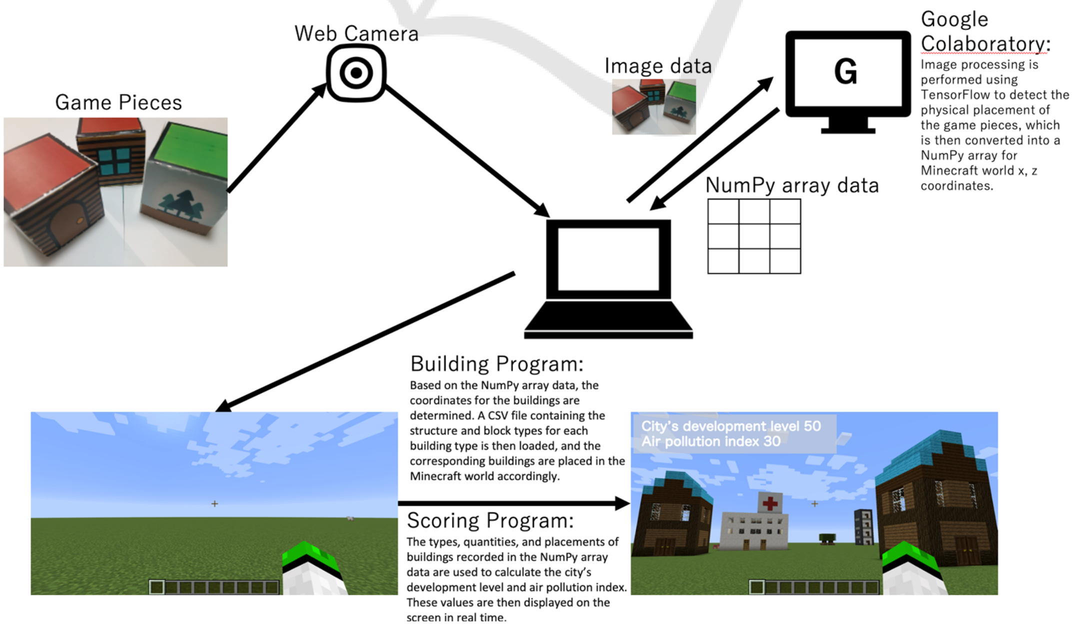


Figure 3: System Overview.

# 3 CONCLUSIONS

This study outlines the development of a game that integrates an analog board game with Minecraft to support learning about urban greening. Despite the recognized importance of urban greening, its complexity, alongside the time, cost, and spatial constraints involved in effective education, has posed significant challenges. This game, with its intuitive controls and real-time simulation, has the potential to improve urban greening education, a subject that has received limited attention in Japanese elementary schools.

The game is designed to promote discussion and simulation-based learning, encouraging students to engage actively in the learning process. Future work will focus on refining the missions and scoring systems based on expert input in areas such as SDGs, STEAM education, environmental studies, and urban greening. Additionally, practical testing and evaluation of the game's educational effectiveness will be necessary to assess its contribution to urban greening education.

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