Designing Learning Activities in Minecraft for Formal Education in Geography

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Abstract—Digital technology has shaped the way humans interact with information and create knowledge. These conditions have in turn shaped a generation of people who experienced virtual environments very early in their lives and are often referred to as digital natives. This group of people has a particular way of communicating and interacting. It characterizes their affinity spaces and the many experiences with virtual worlds and digital games. In digital games, the separation between entertainment and learning is becoming less pronounced. Many game titles have been used for educational purposes. An iconic example is Minecraft, which has been used formally in some schools to teach topics on the environment. However, studies on formal topics in Geography are conspicuously absent, and we therefore selected Minecraft to understand how digital natives learn about Geography given the character of its virtual environment. To this aim, we developed a learning task scenario for global climate zones. The scenario was tested in two pilot studies with two different groups of participants. The results indicate that participants already share some degree of knowledge about the game environment, despite differences within the digital native group. Using the results of the pilot studies, we discuss the design choices to engage players in the game's learning activity.

Keywords—digital game, education, geogame, geography

1 Introduction

Digital natives are people who were born during the digital transformation that has taken place over the past few decades [1]. Having been immersed in digital technology, digital natives interact differently with virtual environments than previous generations. Learning with new technologies is the setting for developing skills related to twenty-first century challenges.

The context of learning in the digital era has shifted the level of complexity in this process. While the focus in the twentieth century was on acquiring basic literacy skills, in the twenty-first century, the process of critical thinking, problem-solving and communication is more important. This includes developing the ability to express oneself persuasively through language and media [2].

In view of how digital technology is changing the learning process, digital games have an important role. The popularization of digital games and platforms in the past three decades has supported an expansion of game culture which already existed. The digital game culture is expanding and forms a part of digital natives' identities. The number of people who play digital games is also increasing, mainly because of the availability of mobile games for smartphones. This is reflected in the figures for the game industry's profits, which ranged from 21.46 billion US dollars in 1990 to 196.8 billion in 2022.

Released more than a decade ago, Minecraft is one of the most sold games in video game history. The game has had an impact on its community, garnering more than a hundred million digital native players since. This context has formed what James Paul Gee [3] calls "affinity spaces", which is a place where teaching and learning processes happen beyond formal institutions and frameworks. In the case of Minecraft, these spaces are formed by a community of players who interact through online forums, Minecraft public and private servers, and in schools which make use of Minecraft Educational Edition. In the context of interaction in these spaces, *"people are fully engaged in helping each other to learn, act, and produce, regardless of their age, place of origin, formal credentials, or level of expertise"* [3, p. 9].

Regarding the pedagogical applications of Minecraft, many examples of content are being produced to address formal and informal learning topics. A variety of prebuilt worlds exist, and in searching for Minecraft worlds with keywords, we found 8 results for 'climate', 265 results for 'biome', 2 results for 'sustainability', 101 results for 'environment'. It shows the relevance of the game to environmentally related content. Among the subjects where the game can be used as media to communicate and engage with students, geography is able to take full advantage of it. However, studies on geography learning in Minecraft are still incipient and investigate geographic issues and concepts such as sustainability, climate change and urban planning [4]–[6].

Despite Minecraft's popularity, influence and potential for learning, examples of studies on topics related to education in geography using the game's virtual environment are yet to be further explored. In this regard, some questions arise on the topic of designing learning activities in the game.

For example, what elements should be considered to design and test a geography learning task using Minecraft? How do we measure the cognitive processes related to the presented scenario?

These questions have guided the design of gamified learning activities in Minecraft, taking advantage of the players' knowledge of the game. To achieve this, we performed exploratory studies using Minecraft to develop and test an educational activity for geography. The motivation came from deliberations on the aesthetics in Minecraft and the mechanics, patterns and rules which have become deeply rooted in former and actual players. We consider that the so far more than one decade of affinity space which has been created around the game has shaped the way digital natives interact with the specific structure of its virtual environment.

To investigate this hypothesis, we proceeded with a four-stage process of research. First, we surveyed digital native participants to understand their profiles related to Minecraft mechanics and aesthetics. Second, we created a prototype for the game, using a topic from the regular school curriculum. The third and fourth stages were pilot studies with different groups of participants. The results of the pilot studies were assessed from the perspectives of design and player experience.

2 Related work

2.1 Environmental storytelling

From the perspective of using digital games for education and training, many concepts such as serious games [7], [8], game-based learning [9], [10] and gamification [11], [12] have emerged. All of these concepts are derived from the game design field. The design principles for analogue and digital games are the same and consider a conceptual game as a starting point. A game can be defined in many ways, but it can be understood simply as a set of rules to be followed to achieve an objective or outcome [13]. Games may be also considered designed systems that offer specific conditions of engagement, rules that lead to stylized forms of interaction [9].

A few decades ago, researchers in the game design field discussed the rules of ludology and narratology in view of classifying what a game is. At the time, Henry Jenkins highlighted that game designers (and researchers) must be attentive to the particularity of games as a medium, specifically in distinguishing them from other narrative traditions [15]. Jenkins defines the concept of environmental storytelling in which the game designer sculpts a 'world' to be played in before any other mechanic or story is created. In the case of a digital game, the player interacts with a virtual environment (2D or 3D) which dictates the possibilities and constraints of gameplay. Interactivity in a digital game is one of its advantages compared to traditional games. The possibility to create virtual environments also enables different design approaches.

In that sense, a digital game can be created to represent real aspects of a place and used as a scenario for educational activities. The structure of the narrative is able to convey the player to an experience directly related to the understanding of his/her surroundings. In the book *Playing with Nature – Ecology in Video Games* [16], Alenda Chang presented examples of games that communicate environmentally related topics to the player alongside the notion of games being designed to express and function as environmental systems. The author also commented on the design choice of providing an open virtual world for exploration. There are many advantages in unstructured play which provide *"the chance to learn about natural processes and life cycles, or how people, animals, plants, and inorganic matter are connected; educated mentorship, or a guiding presence knowledgeable enough to provide more information about what one is experiencing; and hands-on activity with actual consequences"* [16, p. 4].

2.2 Minecraft's virtual world and learning

Among the digital games portraying environmental systems as a part of its mechanics and aesthetics, Minecraft has the spotlight. The adoption of a biome based on procedural world generation set the basis for developing mechanics related to exploring and gathering resources from the environment. An open world and its representation of landscapes gives players the freedom to interact with the virtual environment as they want and to experiment and modify it to test hypotheses. The blocky aspect of Minecraft contains the intrinsic potential for supporting spatial skills development. Carbonell-Carrera et al. demonstrated that the game offers good results and opportunities for improving mental rotation tasks [17].

Considering the game's influence on contemporary digital play, Minecraft has undoubtedly established a new level of using digital games for educational purposes [18]. The game's virtual environment and basic mechanics fulfil an important aspect of effective learning by connecting the game experience with the real world [19]. A survey in Melbourne, Australia, collected information about children's gameplay experiences with Minecraft. The results showed that Minecraft is the most popular digital game title played by children in the age group 3–12 years and that the most frequently used gameplay devices are tablets [18, p. 3294].

Baek et al. conducted a systematic review of Minecraft and education from 28 articles which concluded that the most explored subject using the game was language and arts, followed by information technology and mathematics [19]. The most common activity using the game is play, but examples where students craft, build and modify the game as part of a learning task are also evident. The study showed that the game has a positive effect on students' level of interest, motivation, and learning. However, the authors also noted the scarcity of experimental studies with the game and that qualitative studies are more commonly reported.

Steinbeiß [20] also presented this finding, arguing that a need exists for the groundwork to produce learning environments in Minecraft. The author argued for observations on how specific designs could provide content to influence the learning outcomes. The use of a design-based research model for developing lessons using Minecraft led to the proposal of a tool called the *Steinbeiß-Ruotsalainen Model for Formal, Non-Formal and Informal Learning with Minecraft*. In this model, the learning process takes place in seven stages. It starts with an introduction outside the game environment, followed by an in-game tour, in-classroom evaluations, in-game tasks (quests), a reflection phase, a free to play phase, a second evaluation and rewards. In this model, the teacher's role is a facilitator rather than a figure who imposes.

The game's mechanics apply a simple coordinate system which the players can use to locate themselves. The coordinate system is not natively visible to players, but it can be switched on by pressing the F3 key (Java Edition). It will display a range of information about the game status along with the x, y and z coordinates of the player. Based on this system, the vanilla version (classic with no modifications) contains items related to the coordinate system and navigation. Two interesting examples are 'empty maps' and 'cartography table'. The first item can be created in the game by combining paper and a compass and used to map the player's surroundings. It functions according to a tile system (128x128 blocks). The 'cartography table' allows the player to copy or change the map scale.

Minecraft's virtual world facilitates the creation of custom worlds. Using geospatial data, real landscapes can be recreated in the game. Many examples show the use of real geospatial data to create virtual environments in Minecraft [5], [21]–[26]. The possibility to use real geospatial data in Minecraft allows the creation of virtual environments which can be applied to many different uses. One of them is to recreate a certain landscape for presentation to players. Using interoperability and GIS, Sena et al. [27] created an example of an adventure game to teach about cultural landscapes. Despite not being designed for formal education, the game presented players with several concepts, such as geological risk, geodiversity, heritage, and identity.

In this context, Minecraft provides an immersive experience to learn about environmentally related topics. Content creation benefits from the game's aesthetics by

representing natural elements such as vegetation, topography, geology, and hydrology [19]. However, design decisions also potentially affect the effectiveness of the virtual environment in presenting educational content. Short [28] explained that excessive information exhibited to the student may be overwhelming and that presenting specific content supports a deeper interpretation of educational content. The author suggested that although simulations of the real world such as those in Minecraft can generate engagement and motivation, high levels of fidelity may distract students from the main topic being introduced.

From a game design perspective, there are methods to combine pedagogical use by experimenting with the game design. Designing educational content in the form of a game requires a selection of actions that move the student/player towards the educational content. It is therefore important to think about the type of activity related to the game experience, and although this will vary according to the media and platform the game is played on, all games may be considered a subset of playful activity [16].

Developing an educational digital game is comparable to the concept of experimental game design. In this concept, the design of a process is the focal point of prototyping and testing. Every change in the game process can fundamentally change it, considering that a game is a complex set of design decisions that introduces challenges in isolating and varying a specific factor [29]. One aspect of designing a learning environment in a game is to provide feedback to player actions in the game, thereby supporting knowledge acquisition from the presented content. A reward-based learning environment can function as a motivational tool during formal and informal learning phases, but it is not enough to assure the learning outcome [20].

To address all these aspects in designing a learning activity in Minecraft, playtesting is an important part of a game's development process. In the early stages of prototyping, designers usually invite colleagues to playtest and give feedback. However, *"internal playtesting very easily turns into designers designing for themselves rather than the intended audience"* [22]. In this case, it is preferable to playtest the game with the target group to ensure that the proposed activity design suitably communicates the content.

3 Methodology

The first stage of the study started with a survey of digital native university students, the second stage implemented and play tested prototypes (Figure 1). This stage was conducted from September 2021 to February 2022. The survey was designed to extract information about the general aspects of players' profiles and experiences with Minecraft. This step gave us some understanding of how players and former players recognize textures in the game's environment. The questionnaire contained two sets of questions, seven questions for the first and nineteen for the second. The first set asked about previous experience with the game and content; the second set tested knowledge of the game's aesthetics. Specifically, the participants were asked to identify the blocks from different game versions. Depending on their previous experience, they would recognize it or not.

The survey's results supported the selection of a geography curriculum topic that would be explored using the game's environment. The current geography curriculum

for K-12 in the Czech Republic was consulted to identify potential topics for exploration with Minecraft. As a topic, we selected global climate zones, as Minecraft would be able to link block textures to specific types of environment. This feature arises from the game's block texture aesthetics and biome representation. The selected topic explored the distribution of five climate zones classified by Köppen: wet tropical, dry, mildly warm, mildly cold, and polar. Each climate zone is specified by a series of environmental conditions, such as precipitation and air temperature.

The conceptual design for the prototype employed Minecraft's mechanics for teleporting the player from a platform to a selected climate zone, pulling levers and pressing buttons. This mechanic supported the following tasks related to a quest-based exploration in game.

Producing the tasks using Minecraft was based on the methods and techniques presented by de Sena et al. [27]. The principle involved using geospatial data to create a Minecraft virtual environment, followed by establishing the game mechanics using a set of modifications. Blocks (textures) were assigned to depict each climate zone: wet tropical (A) – jungle forest biome blocks; dry (B) – desert biome blocks; mildly warm (C) – savannah/deciduous forest biomes blocks; mildly cold (D) – spruce/tundra biomes and podzol blocks; polar (E) – cold biome, ice, and snow blocks. The second stage of the methodological process is detailed in the following sections.

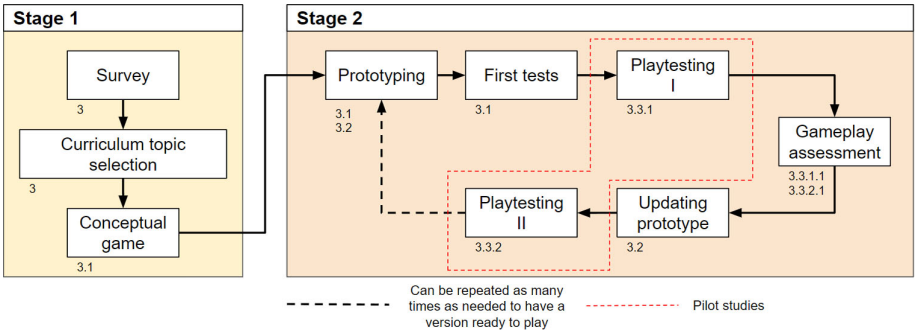

Fig. 1. Methodological process

3.1 Prototyping and first tests

The Minecraft aesthetics, which represent procedurally generated landscapes based on biomes, supported our decision to depict global climate zones in the proposed educational task. For game design, we selected the development approach proposed by Fullerton [30]. For the game activity, we designed a conceptual model which incorporated Minecraft's mechanics and followed the form of an exploratory quest. In this activity, players would be able to explore the climate zones and interpret the main environmental features. The concept aimed to stimulate thinking about the geographical aspects of the environment in relation to each climate zone. The activity invited players to gather information from the environment to answer questions and accomplish quests.

The virtual environment was created according to the basic rules stated in the conceptual game. The game was developed for Minecraft Java Edition, version 1.16.5. All prototyping and playtesting were done using Forge 36.2.0, which permits modifications to the standard version of Minecraft.

3.2 Creating the virtual environment

The virtual environment was created using software and several tools for working with geospatial data and Minecraft. First, we recreated a map of the climate zones to be displayed using the same block textures encountered in the game. The model was produced using a combination of ETL software (FME) and applications for creating a Minecraft map (Mineways,[1] Amulet[2] and WorldPainter[3]). Raster and vector data were combined to create a terrain model with a layer of blocks representing five climate zones. Each climate zone was depicted by a specific Minecraft block which suitably represented the zone's characteristics, as mentioned above in Section 3.

The Minecraft world was designed to represent five climate zones and incorporate the general environmental features that characterize each zone's biome and landscape. Minecraft's aesthetics and mechanics feature the concept of biomes, and each biome has its own set of blocks and textures. For this reason, and considering the massive community of players, the blocks are easily recognizable by players.

WorldPainter software was an ideal tool to create the representations for each climate zone since it allows modification of Minecraft worlds. Using this software, we produced a model for each of the climate zones, with two variations for the mildly warm climate zone (CI and CII) (Figure 2). Using a selection of custom brushes, biome layers and terrain properties, it was possible to create islands where the player would have the feeling of being in a specific climate zone. To prevent players from seeing other islands from a distance, we defined a render distance limit, and to prevent players from swimming or sailing from one island to another, we applied barrier blocks to create a bounding box. The terrain for each climate zone consisted of the blocks described above, providing a visual link to the textures represented in the map room.

A selection of game modifications added the mechanics which allowed us to apply the concept. The main modification was Custom NPCs.[4] Created by the player Noopes_, this modification provides non-playable characters (NPC) in the java version of Minecraft and allows the introduction of dialogues and quest systems and scripting with commands, etc. Another modification we used was Dynamic Surroundings. Created by the player OreCruncher, the modification adds ambient sounds according to the Minecraft biome the player is in.

[1] https://www.realtimerendering.com/erich/minecraft/public/mineways/
[2] https://www.amuletmc.com/
[3] https://www.worldpainter.net/
[4] https://www.curseforge.com/minecraft/mc-mods/custom-npcs

When the player first enters the game, he/she is located inside a map room (hub) which has a climate zone map displayed on a wall (Figure 3). Below the map is an interactive panel that works also as the map's legend. Each block texture is identical to those on the wall map. The hub also contains an NPC (teacher) who explains the task and invites the player to explore the climate zones by pressing the buttons on top of each block in the legend. The NPC is interactive; the first interaction therefore is to start a dialogue with the teacher and obtain information on how to start the task. The teacher presents the task as fieldwork/exploration of the Earth's climate zones. The task is based on a fetch quest system, where the player must visit all climate zones and collect plant samples from three of the five different environments.

In each climate zone, the player encounters NPCs who ask questions about environmental features in the surroundings. These multiple-choice questions can be responded to as often as the player wants until they give the correct answer. Feedback as sound lets players know when their answers are incorrect (sound of an explosion) or correct (sound of a bell).

Along the way from one NPC to another, the player will encounter wooden signs with basic information about the visited climate zone. The signs display short sentences with descriptions of fauna, flora, and physical aspects of the terrain (Figure 4). These signs are located in places near pathways and in spots visible from a distance. In climate zones with a tree cover the signs are closer together, whereas in open view they are scattered.

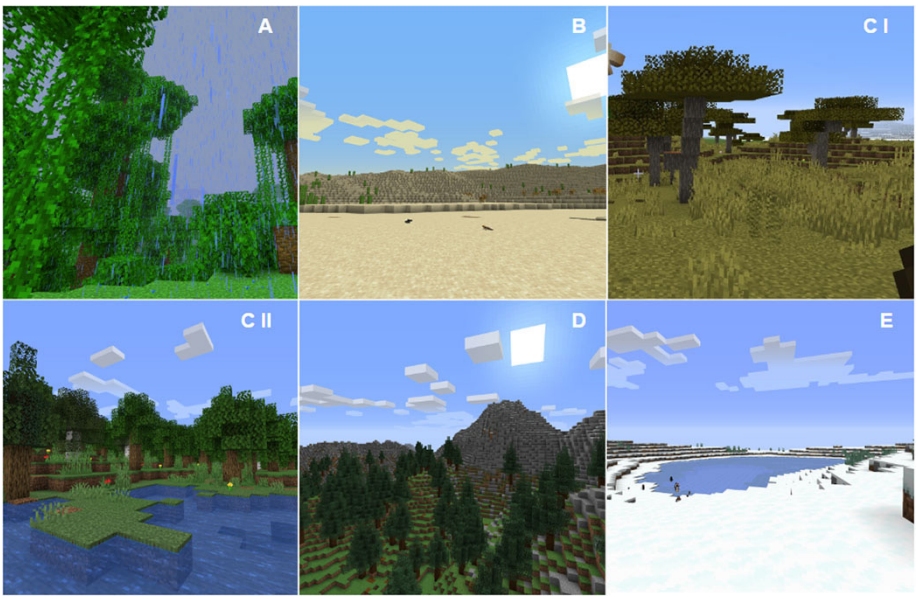

Fig. 2. Climate zones where the player is teleported to after interacting with the legend panel. Climate zone C has two representations (C I: savannah, C II: deciduous forest)

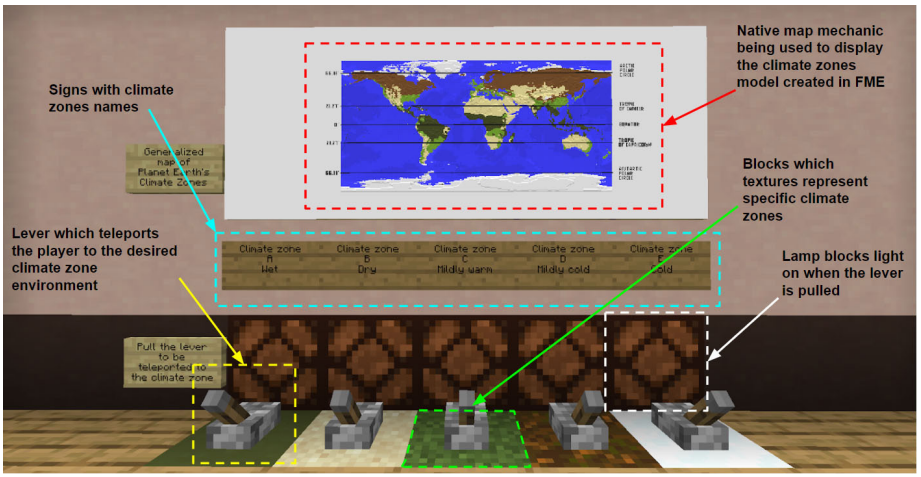

Fig. 3. Interactive panel with sample textures for the Earth's climate zones (version from pilot study II)

Fig. 4. Examples of information about climate zones in signs positioned alone the exploration route (pilot study II)

3.3 Playtesting sessions

Prototype testing was based on the interactive game design model proposed by Fullerton [30]. In this model, the prototype is developed and tested in four stages: concept, pre-production, production, and questions/answers. In this approach, the early-stage prototype is tested by its developers to validate the implementation of the conceptual game. After validation of the conceptual game, the prototype is tested as often as required to validate design choices, fix bugs, and assess the user experience. In the case of our study, two prototypes were tested by participants.

The logic behind prototype development was to use the assessment of the previous version to produce a new, improved version. The first prototype was created according

to the premises presented previously in addition to testing conducted by the authors and colleagues. The second prototype was updated according to the results from the first playtesting session (described in the following sections).

The first prototype applied the recommendations in the notes from conceptual game testing. The second prototype was updated/fixed using the data collected during the first playtesting session. The second playtesting session assessed the entire course of the game and its mechanics. The data collected from both playtest sessions were then assembled to support the discussion in this paper. Playtesting was performed in June 2022 and consisted of two pilot studies.

Both game versions were developed in English, with dialogues and quests translated into Czech only for the first playtesting session. The game was designed for offline play, but it is also available on an online server.

Playtesting session I. The session presented the scenario to high school level students. The aim of the study was to test the mechanics of exploring the environment to accomplish the quest and answer questions. In this prototype version, players were required to visit the climate zones and talk to an NPC, who asked a question about the local fauna. Animals were added to the environment to provide visual and audio clues for the player. To insert animals, we used *WizardAnimals*,[5] a modification created by gustavowizard123.

The game starts in the map room, where the players find a lectern with a guidebook containing the main rules of the game plus. The room also contains a chest with goods, maps on the wall, and an NPC (teacher) who send the player on a quest for plant samples. Players decide how to start the game by interacting with any of the features found in the map room.

Setting and procedure. A laptop with a 13″ screen was prepared for the players. They played in pairs, with no predefined rules, and could set how to share their game experience. A brief explanation of the exercise translated from English to Czech was given to all participants at once. The time to finish the game was measured, and notes were taken while players tested the game. When it was necessary, the researcher also issued instructions or information about controls or game mechanics. General observations and notes about user interaction with the features and responses to sound feedback were recorded during playtesting. After finishing, the players were invited to comment or make suggestions about the scenario, written in Czech if they wanted to share some thoughts.

Participants. High school students from a technical college in Brno, Czech Republic, were invited to participate in playtesting. Eight participants tested the game, consisting of five boys and three girls, aged 15 to 16 years. None of the participants wanted to speak in English, but they were all able to understand and read the language.

Playtesting session II. In this prototype, the question task was improved by adding a structure to the experience. Each climate zone presents the player with three NPCs who ask a specific question related to one of three topics: the physical environment, fauna or flora (Table 1). After correctly answering the questions, the player is able to unlock the plant sample quest with the NPC in the map room. The main objective of this

[5] https://www.curseforge.com/minecraft/mc-mods/wizards-animals

playtesting session was to verify whether the structured task system based on questions would engage players in the topic of climate zones.

Some features were implemented to improve the representation of each climate zone. For example, when the player is teleported to the tropical wet climate, it triggers a command to start raining. Based on the previous playtest, we noticed that players should have cues to lead them through the environment to reach the newly added NPCs. Pathway blocks were placed to create a visual reference for players to identify where they should head to accomplish the task.

Table 1. Structure of the questions

Climate Zone	N°	Question Pattern
X	1	Question about flora
	2	Question about physical aspects of the climate zone
	3	Question about fauna

Setting and procedure. The game was prepared for two players to play at the same time on a laptop, using a single avatar in the game. The game was displayed on a second 21″ monitor placed above the laptop screen. A map of the keyboard with the functions was displayed on the laptop screen throughout the gameplay.

Before starting, an explanation of the purpose of the study and what kind of task players would perform was given to the participants. Gameplay was recorded using screen capture from the Xbox Gaming app, with microphone recording. General observations and notes about user interaction with the features and modifications used, specifically *CustomNPCs* and *WizardAnimals*, were recorded during playtesting.

After finishing, the players were invited to answer a questionnaire in Google Forms. The questionnaire contained questions about their experience with Minecraft and also invited the participants to leave comments or make suggestions.

Participants. University students from Masaryk University, Brno, Czech Republic, were invited to test the game. Playtesting was conducted over a day with eight participants aged 20 to 25, four men and four women. All of the participants were Information and Library Science students and were able to read and speak in English.

4 Results

4.1 First survey

The survey was performed with a group of university students from three different cities (Brno, Olomouc, and Sofia). For the first set of questions, 36 respondents provide information about their previous experience with Minecraft. Almost 70% of the participants had played Minecraft previously, and 58% of them had watched Minecraft content on YouTube. The average age when they started playing Minecraft was 13 years old. When asked about the platform to play the game, 92% responded that they used

the PC version and 8% used a mobile device. The majority of the participants played Minecraft for less than one year, 20% one to two years, and 12% played the game for more than 7 years.

The second questionnaire was answered by 28 participants from Brno and Olomouc. As mentioned in the methodology section, the questions concerned block textures and their respective Minecraft versions. In response to the question about the granite block (version 1.8), 35.7% of answers were correct. Similarly, the responses to questions concerning the basalt block (version 1.16), were correct in 32.1% of answers, and for the copper block (version 1.18) 42% of answers were "I don't know". For the classic and older block textures in the game, the results were different, and most of the participants responded correctly. For the question about the sand block texture, which was introduced to the game in 2009, 92.1% of answers were correct. Similar results were obtained from the question about the snow block, also from 2009, with 89.3% of answers correct.

4.2 Playtesting session I

On average, participants took 11 minutes to finish the game, and participants interacted with each other throughout the task. Three pairs of participants decided to share the game's controls, where one participant controlled the mouse (head/sight movement, break/place blocks) while the other controlled the keyboard (walking/running, jumping). At some points, participants stopped to discuss which direction to follow or discussed the answers to questions from NPCs.

The first pair of participants ignored the NPC in the map room and travelled immediately to the climate zones. It took them a while to realize that the NPC was interactive. The players struck at some animals while exploring. They also investigated details in the map room, such as the source map for the creation of the climate zones. Participants checked the quest log window several times to confirm how to finish the plant sample quest. They answered all the questions correctly at the first attempt.

The second pair of participants were confused with the controls and attempted to interact with the NPC while holding the guidebook with the avatar. While interacting with the NPCs, the players received hints from the researcher to help them figure out the mechanics. After some time, the players managed to finish the task, answering all questions correctly at the first attempt. These two players explored the environment much more than other participants.

The third pair of participants started by reading the guidebook before interacting with anything else in the map room. The sound effects for NPCs and animals was a feature that caught their attention. They struck at some animals while exploring the climate zones. At the start, the players did not follow the main task and explored the environment instead. When the players attempted the sample collection quest, they had to read the Minecraft wall map to discover where to find Acacia leaves. Looking at the map, they decided to teleport to climate zone C (mildly warm), which was the correct zone. They answered one question incorrectly.

The fourth pair of participants were the quickest to complete the test, finishing the game in just six minutes. The pair were a boy and a girl playing together, but the boy immediately took control of the game from the beginning while the girl mainly watched

him play, commenting and suggesting actions to take. They struck at all the animals they found on their way and paid more attention to the signs and blocks on the floor to identify the climate zones and decide which one they should visit. They did not pay much attention to the maps displayed on walls. Neither of the participants was willing to comment on the gameplay, but both mentioned that it was fun.

4.3 Playtesting session II

Eight participants tested the game in the second playtesting session. Seven of them had already had some experience with the PC version of Minecraft (Java/Bedrock), whereas one had never previously played the game. Among those with previous experience, the average age when they started playing was around 10 years, and the majority played on online servers. The average age of the participants at the time of this test was 22 years. All the participants shared the same background in information and library studies. On average, the participants had played Minecraft for at least 3.5 years.

The results from the gameplay assessment showed that all players accomplished the given tasks in the game (Table 2). An examination of the gameplay videos verified that the pathways introduced only in the second prototype were effective in leading the players to the NPCs. As in the first prototype, the participants interacted with animals in every visited climate zone. A flaw in the NPCs system confused one pair of participants, who consequently struggled to understand the dynamics of travelling to the next NPC after answering the first question. This problem occurred because the Custom NPCs mod randomly displayed the interaction lines, causing the misunderstanding.

Table 2. Gameplay assessment

Assessment Topics*	Participants			
	1/2	**3/4**	**5/6**	**7/8**
Percentage of incorrect answers	13.3%	20%	26.6%	6.66%
Percentage of signs read	32%	48%	24%	24%
Consulted the climate zone map	Yes	No	Yes	No
Interacted with animals (striking/petting)	Yes	Yes	Yes	Yes
Collected plant samples from the correct climate zone**	Yes	Yes	Yes	No
Explored the environment***	Yes	No	No	Yes

Notes: *Information retrieved from the recorded gameplays, **At the first attempt, ***More than intended by the game.

All participants started paying more attention to the signs after visiting the first climate zones. Signs that were placed near the paths were more often spotted than signs placed away from the main route. In climate zones B and E, which lack vegetation, participants spotted the signs more frequently. In assessing knowledge retention from the experience, all participants answered correctly for the number of visited climate zones, which hemisphere the mildly cold zone was located, and whether the climate zone affected the fauna and flora. Participants who explored more the environment had higher percentage of correct answers.

All the NPC questions were answered by the participants. Questions 5, 8 and 11 were answered incorrectly more often than others, with only two pairs of participants answering them correctly at the first attempt. Participants answered questions 2, 13, 14 and 15 incorrectly once, and the remainder were answered correctly at the first attempt.

The responses from the questionnaire given to the participants after playtesting also provided interesting results about the player experience. In response to what the player liked most, some players remarked that being in and exploring an open world was a major highlight from the experience. Interaction with entities (animals) also revealed itself as one of the most engaging features of the game. These observations were derived from the questionnaire responses below:

> *"Reading signs, tasks, just running around", "Running around landscape and interacting with flora and fauna", "Collecting samples", "walking", "Cooperating with my teammate, exploring", "Animals", "The animals".*

In response to what participants missed in the game most, participants indicated that they would like to see more interactivity and higher levels of difficulty in the questions. Participants also mentioned that the quest system could be developed further to include more options for players to choose from and greater diversity in the tasks:

> *"Maybe more interactivity, harder questions", "It can be longer and have more quests", "More quests in the form of collecting", "nothing comes to my mind at the moment", "Diversity in characters, questions and quests", "More interaction with the animals".*

The final question asked participants about the drawbacks of the Minecraft Climate Zones game. In this part, participants expressed that the game recalled experiences of reading textbooks, mainly because of the dialogues, texts, questions, and repetitive tasks. One participant mentioned that the game might be uninteresting to older people. In relation to the elements designed for the environment, one participant commented about distractions and that pathways were sometimes not visible.

5 Final considerations

Minecraft is already known as a powerful tool for education, being used in many formal and informal educational settings. Its popularity plays a key role in engaging students in an educational activity; however, it is not enough to create an attractive setting for students. It is therefore pertinent to think about designing Minecraft game experiences which support learning processes. In the present study, we set out to understand the role of the game's virtual environment in creating a context for learning about topics related to geography. Overall, the study presented the usefulness of Minecraft aesthetics in creating lessons for geography curriculum.

Minecraft is an Earth simulator, with animals, oceans, mountains, trees, weather and a day/night cycle. All these elements recall real-world features which are recognizable to players. Exploration is one of the main aspects of the Minecraft gameplay, as discussed by de Sena [27]. In the present studies, we engaged players with an exploratory activity in Minecraft by providing climate zone content to interpret the environmental

simulation. However, as suggested by Short [28], an excess of realism and detail may distract players from the main objective. Considering this observation, we introduced visual features in the environment in pilot study I and II to support players with exploration and accomplishing the task.

The design-based research using Minecraft is a useful combination for developing educational activities. The results from our research will support the next stages for developing the use of Minecraft in geography teaching. Whereas the prototypes were not played in a formal class context, we aim to improve the scenario and set up an actual class exercise. Using the game in a real-world scenario can provide an environment for assessing different aspects of the gameplay.

The survey demonstrated that different affinity spaces exist in just one digital game. In the case of Minecraft, which has been available for more than a decade, the community of players has changed significantly since the first game release in 2009. Former Minecraft players in the participant groups spoke about the game during playtesting with a feeling of nostalgia. We consider that the more than one decade of Minecraft play has shaped the way digital natives intuitively communicate and interact with the game's specific structure and virtual environment aesthetic. Nevertheless, additional studies are needed to validate this hypothesis.

It is important to remark that the survey and playtesting were performed by three different groups of people with varied backgrounds. Their input was relevant to understanding how the proposed game motivates the player. However, the game still needs to be tested by the target audience, which is K-12 students. In that case, the game will be improved to its final version before testing by children. This corroborates the notion that designing for a target audience requires playtesting with that specific group, otherwise the final design may not have the desired learning effectiveness [22].

One aspect of designing educational content in Minecraft is the required skills for a teacher to implement the scenario. A Minecraft world can be designed by an instructor be used for more than one topic. The game can encompass a series of lessons as a combination of different areas [28]. The present study explored the possibility of using the advantage of the game's aesthetics to address a topic from the K-12 curriculum. However, using the principles of experimental game-design research, similar lessons with the same tools and design could be created. In this aspect, the possibility to modify Minecraft's virtual environment and mechanics allow "even less computationally skilled researchers to expand their research focuses on educational video games" [31].

There are many ways to assess the outcomes of an educational activity in Minecraft. Recording gameplay was effective in registering all the actions taken by players in the game. Reviewing gameplay demands a significant investment of time, which is not appealing in a formal learning setting. However, it is very effective in improving the design, giving the designer the means to easily track flaws in a designed activity. From the assessment strategies employed in the studies, it was not clear whether the participants retained any content after finishing the game. Considering the use of the proposed game in a classroom context, the introductory and evaluation stages administered by a teacher can encourage thinking in students, as discussed by Steinbeiß [20]. Future studies can focus on assessing information retention and knowledge recall.

The presented game was designed for offline play, but since Minecraft allows online play via servers, the game could be adapted to an online multiplayer mechanic. It would be able to encourage the development of communication, cooperation, and

problem-solving, all highly relevant skills in the twenty-first century. Still, online interaction via the game does not necessarily generate social learning and raises the risk of unwanted behaviour. In that regard, a moderator would be necessary to encourage interaction between players [31]. The setting supports discussion between players and the development of reasoning skills [14]. Despite that the proposed game was designed to be single player, allowing the participants to play together on the same computer and control a single avatar proved an effective method of encouraging communication and knowledge transfer.

We conclude by stating that we believe Minecraft should not replace in-person classes or well-established traditional teaching methods. Our intention was to explore and gain a better understanding of Minecraft's influence on a generation and the effect in learning processes, specifically in geography curriculum. The game already plays a role in educating players and supporting the development of many skills highly relevant in the twenty-first century, for example spatial thinking [14], creativity [32], citizenship [33], and STEM [28]. We also consider the use of Minecraft for educational purposes must come with responsibility, considering that the intense use of digital media, such as digital games, raises concerns regarding addiction [34]. Lastly, other game engines also influence the development of technology skills and digital literacy among students, like the digital game Roblox [35].

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