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Minecraft as a Hybrid Boundary Object: Exploring Nature in Squares

Anne-Marie Cederqvist [1,*] and Maria Impedovo [2]

[1] School of Education, Humanities and Social Sciences Halmstad University, 301 18 Halmstad, Sweden
[2] ADEF, Department of Education, Aix-Marseille Université, 13013 Marseille, France; maria-antonietta.impedovo@univ-amu.fr
* Correspondence: anne-marie.cederqvist@hh.se

Abstract: In this exploratory case study, we investigated children's ways of experiencing virtual worlds, such as Minecraft, and how this may affect their understanding of nature, scientific phenomena, and sustainable development; that is to say, Minecraft was explored as a boundary object in children's making activities with Minecraft. The research questions that guided the study are: In what ways may Minecraft act as a boundary object between children's formal and informal learning about science and sustainable development? In what ways may Minecraft act as a boundary object when children build relationships with nature? Semi-structured interviews were conducted with six children. A thematic analysis approach was used to analyze the interviews. This study shows that in the Minecraft context, the children gained a breadth of everyday experiences related to scientific phenomena and sustainability. Further, the findings indicate that children merged their experiences in the virtual world with experiences in the physical world. In this sense, Minecraft involves science and sustainability content that crosses the boundary between the virtual world and reality. Thus, we suggest that Minecraft bridged children's physical and virtual relationships with nature; that is to say, Minecraft became a boundary object that allowed children to experience nature and encounter knowledge that they would not otherwise have been able to experience.

Keywords: science education; sustainable development; virtual world; boundary object; making; minecraft

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1. Introduction

The rapid development of digital technologies affects all levels and parts of society, as well as education to prepare future citizens [1]. Digital technologies have become a natural part of children's lives, creating new cultural conditions for their development [2]. The massive use of digital and educational technologies outside of the school walls leads to children being involved in new, less formal border-centric ways of experiencing phenomena and situations in the natural world.

To date, attention has been given to the ludic and making activities [3,4] that may mediate concept formation in formal or informal contexts [5]. Further, there is a growing interest in early childhood education in how children interact and learn through new technologies [6]. Through play, children make sense of their environment [5]. Multimodal activities are embedded in ludic digital environments, such as video games, which are widely used in children's everyday activities. In digital environments and virtual worlds, children gain everyday experiences of phenomena that they bring into the classroom. Previous research in science education suggests that children make sense of their everyday experiences by building mental representations that they later use to understand phenomena in a classroom context [7,8]. However, we still know little about how children experience virtual worlds, such as Minecraft, and how this might affect their understanding of scientific phenomena and, more broadly, their understanding of sustainable development.

Therefore, this exploratory case study focused on children's video game play in an informal context as a resource for learning science and sustainable development (hereafter,

SD). Specifically, we sought to trace and analyze the game Minecraft (https://minecraft.net/, accessed on 15 May 2023) as a boundary object (hereafter, BO) between formal and informal learning of science and sustainable development. We chose Minecraft because it has had a significant impact not only on video games in general but also on education and research worldwide [9]. We would like to note that alternative open-source games are available that offer an experience similar to Minecraft, like MINETEST, which has a rich content library and contains many user-generated mods, games, and texture patterns. Other open-source alternatives are VELOREM, Terasology, TrueCraft, Craft, Voxel.js, WebCraft, Freeminer, ClassicCube, and WolkenWelten. Minecraft is analyzed here as a BO. Sociologists Star and Griesemer [10] first introduced the term "boundary object" to describe the artifacts, discourses, and processes that connect different community perspectives to achieve a common goal.

BOs are objects that are both plastic enough to adapt to the local needs and constraints of the different parties employing them, yet robust enough to maintain a common identity across sites. In using a BO, it is possible to come across pieces of knowledge that would otherwise be inaccessible and hinder the sharing of practices.

Given the above, a BO is a connector between different communities, allowing for the extension and enrichment of the practices of the community itself: boundaries are "sources of new opportunities as well as potential difficulties [. . .]. Boundaries can create divisions, be a source of separation, fragmentation, disconnection, and misunderstanding [. . .] they can also be areas of unusual learning, places where perspectives meet and new possibilities arise" [11] (p. 233). Therefore, the practice that is negotiated and developed through the use of a BO is not static, but rather a lively practice that is constantly in change.

Given this analytical perspective, the research questions were as follows: In what ways may Minecraft act as a boundary object between children's formal and informal learning about science and sustainable development? In what ways may Minecraft act as a boundary object when children build relationships with nature?

Minecraft was explored as a boundary object in formal and informal learning about science, SD, and as a BO between the physical and virtual nature.

In the following, a theoretical framework is proposed, followed by an empirical data analysis.

2. Theoretical Framework

2.1. Children and Technical Objects

Regarding everyday objects, it is impressive to see the number of objects that children are confronted with [12]. Technical objects and technology are part of children's lives. Children learn and, at the same time, structure themselves through their environment.

All technical objects are carried by onboard technical expertise. Indeed, technical objects are considered everything that has been transformed, embedding knowledge and technique in its materiality and use. More precisely, Rabardel [13] defines technical objects as "everything that has transformed human origin (. . .), which is ready to be used, developed to be part of finalized activities" (p. 59). Further, children form ideas and understandings from everyday experiences through physical activities, exposure to media, and interactions with other people [7]. With the current rapid technological development in society, it has become increasingly important to understand how new digital technologies create new cultural conditions for children's development [2], as well as how digital technologies affect children's ways of experiencing phenomena and situations in the natural world.

2.2. Students' Everyday Experiences in a Digital World—A Basis for Learning Science

When students arrive in the science classroom, they already have ideas and prior understandings about things that the teacher will bring up in the lesson. von Glaserfeld [8] suggests that students make sense of their experiences in everyday life by building mental representations, which they later use to understand new things and situations in the classroom context. Thus, students' prior understandings are important in the learning

experience [7]. Students' prior understandings often differ from accepted scientific understandings. Therefore, teachers need to be aware of what prior understandings the children bring to the classroom [14]. To organize teaching that promotes students' learning in science, it is therefore necessary that the teacher take into account students' prior understandings when planning learning activities.

In science education research, students' prior understandings have attracted attention for several decades and are considered important for organizing teaching about scientific phenomena.

Thus, it could be argued that we have a broad picture of what prior understandings of scientific phenomena students bring to the classroom based on their experiences in everyday life. However, digital technologies have changed the nature of childhood and, hence, students' experiences in everyday life, and today, it is necessary to recognize an understanding of students' everyday life based on the use of technologies [15]. This means that today's students' prior understandings of science may be different from those expressed by previous students just a decade ago. Students' social worlds of today are saturated with digital technologies, and their digital childhoods influence their everyday experiences [16]. In their spare time, they play games, socialize with friends online, and spend more time indoors than previous generations. Their everyday lives incorporate the virtual worlds of computer games, such as Minecraft. The combination of spending less time outdoors and more time in virtual worlds is likely to affect the way students experience the world and the everyday experiences they bring to the classroom. In science education, this is likely to affect how students experience phenomena in natural environments. However, we still know little about how students incorporate virtual worlds, such as Minecraft, into their everyday life, and what everyday experiences they bring with them. We can assume that their experiences may include subject content related to the school curricula, such as science. However, there is still research to be done in this area. The following section focuses on Minecraft and its possible implications as a BO.

2.3. Minecraft as an Actor for Digital Literacy

Minecraft is a sandbox video game based on free play with self-setting goals. In Minecraft, players explore a randomly generated 3D world made up of blocks that they can break down and use to build structures, tools, weapons, and other virtual resources that can be used in the game. The game has two main modes: survival mode, where players must gather resources and fend off monsters to survive, and creative mode, where players have unlimited resources and can build anything they want without restrictions. The main activity in Minecraft is playing with the virtual resources available and building new digital resources. Within the game, the players experience a natural space that is made up of cubes representing different elements of nature, such as rock, sand, earth, water, wood, plants, and animals. Minecraft was not explicitly designed for educational purposes. However, Minecraft has had a significant impact on education and research around the world, as it was suggested to promote creativity, collaboration, and problem solving, as well as help students learn to code [9]. However, today there exists an educational version, Minecraft Education Edition, which has been developed to fit educational purposes more specifically.

As previously suggested by Deuzanni [17], Minecraft can provide children with digital literacy practices of importance in their everyday lives. Furthermore, the review by Nebel et al. [18] shows various beneficial characteristics of the game. For example, Minecraft provides ecological systems, including different kinds of plants and animals. In these ecological systems, the player can manipulate the environment and create farms that are optimized for the player's benefit. Thus, the player can influence the ecological representations within the systems [19].

In the following two sections, we focus more on the exploration of Minecraft in two main dimensions: between formal and informal learning of science and SD, and as a game for mediating the physical and virtual setting of children's making in Minecraft.

2.4. Minecraft between Formal and Informal Learning of Science and SD

Education for sustainable development is defined as education that encourages learners to gain the knowledge, skills, attitudes, and values needed to shape a sustainable future [20]. It is suggested that new technologies could support and be a driving force in achieving the Sustainable Development Goals of the 2030 Agenda for Sustainable Development [21]. Furthermore, Trott and Weinberg [22] argued that science education is a key venue for a rapid societal transformation toward sustainability. From a science education perspective, the issues of SD call for teaching that promotes children's interest and understanding of scientific phenomena, such as biodiversity, ecological systems, and climate change. Trott and Weinberg suggest the positioning of children as critical actors to strengthen their engagement, which allows them to think about science and sustainability issues in new ways.

Kumpulainen and Kajamaa [23] described the importance of children's ownership of their learning process, which can also be described as the agency of learners and how they shape their identity as learners. To promote children as critical actors, we need to find new ways of letting children approach science and sustainability issues [24]. We need to identify learning approaches that stimulate and educate individuals as agents of change [25].

Children's agency is an interactive process between a child, other people, the context, and the environment [26,27]. Children's agency is shaped over time by encountered situations and experiences which they question, elaborate on, and react upon, depending on the context and how the environment responds [26,28,29]. Today, children experience situations and environments through digital technologies, such as video games, which influence their ways of understanding phenomena and shaping agency in the natural world. In light of students' disaffection toward science and technology education, Vereijken et al. [30] suggested that new links and solutions are required to promote students' autonomy and creativity, which involves moving within, across, and beyond disciplines. Video games, such as Minecraft, are interesting from this perspective, in combination with learning science and education for sustainable development.

Increased interest is one reason why educators use games in general and digital games in particular. Interest is a multifaceted phenomenon: personal or individual interest means an intrinsic desire to understand phenomena that holds over time, whereas situational interest is an ephemeral, context-specific interest [31].

Minecraft has received a lot of attention in the educational literature and STEM education in the last few years. In the next section, the game is examined from the perspective of Minecraft being between the physical and virtual relationship with nature.

2.5. Minecraft between the Physical and Virtual Relationship with Nature

Maker-centered activities emphasize the transition from being a knowledge receiver to being an active knowledge-builder [32]. Tan [33] addressed the idea that students' knowledge could be considered more intimate in maker-centered activities. This "ephemeral" knowledge, complementary to the official content, becomes a form of performative knowledge.

Virtual making has been widely explored in recent formal science education, focusing on multimodal and affordance opportunities [34,35]. The focus on virtual-making activities is an aspect of great interest in the use of video games.

The use of the virtual setting to explore contexts, as it is possible in Minecraft, opens new layers of means making. For example, the virtual avatar is seen as an extension of the body and, as such, a vector of emotion that mediates cognition [36]. Indeed, in virtual reality, the body becomes the primary interface for interaction, manipulating the available information at two embedded levels: that of the physical body using the human–machine interface, and that of the virtual body. The virtual reality experience thus involves cognition, emotion, and imagery in a new narrative.

In Minecraft, nature lives on the screen, providing an authentic form of embodied experience. Crossing boundaries between different realities, the virtual and the real nature, as in our case, becomes a means to "open the opportunity for thinking/feeling/knowing

differently—in particular in more sensory and collective ways" [37] (p. 265). Individuals are constantly merging their experiences in the virtual world with experiences in the physical world. Hence, the united experiences can be seen as embodied skills and competencies that bridge the two worlds [38]. In this sense, Minecraft may involve science and sustainability content that crosses the boundary between the virtual world and reality. Playing Minecraft involves creating ecosystems by applying scientific knowledge when manipulating digital materials [17]. Furthermore, Deuze [38] suggests that children construct embodied practices that bridge the physical and virtual worlds, developing understanding and creativity. Thus, virtual making, as in Minecraft, has the potential to bridge children's physical and virtual relationships with nature, i.e., Minecraft may have the potential to be a BO between physical and virtual nature.

3. Methodology

This study was part of a broader project on digital literacy and ESD inside the European project, COST, titled PHOENIX. (https://www.cost-phoenix.eu/, accessed on 18 July 2023), which direct attention toward the protection, resilience, and rehabilitation of the damaged environment. Within the project, a massive inquiry (in press) explored young people's attitudes toward eco-citizenship. In addition, a number of explorative interviews and observations [39] are being conducted with children and young adults.

In this exploratory case study, we aimed to gain an empirically grounded understanding of children's ways of experiencing virtual worlds, such as Minecraft, and how this may affect their understanding of scientific phenomena and SD. The research design included semi-structured interviews to conduct a detailed examination of the case [40], which was expected to provide rich details of real-life situations that are essential for the development of a refined view of reality [41].

This study used data gathered from semi-structured interviews with six children. The sample size was insufficient to draw any general conclusions from the findings. However, the qualitative data can be considered rich and provides an in-depth insight into how children experience virtual worlds, such as Minecraft. By providing excerpts of what the children expressed during the interviews, a detailed account of the research object was presented. As such, this case can be seen as an exemplifying case of children playing Minecraft, where the aim was to capture the conditions of a common situation in everyday life [41]. Therefore, the findings can be seen as a contribution of knowledge to a given research field [40,41], which may point out the direction for further investigations on the same topic, namely, to understand Minecraft as a BO for children's learning of science and SD.

3.1. Participants and Interview Protocol

The protocol of the qualitative research was shared among the interdisciplinary (education, psychology, and urbanism) educational research group interested in this topic.

In this framework, a specific interview protocol was developed for children (over 6 years old) who play or have played Minecraft (Appendix A). The interviews were conducted at multiple sites (Italy, Croatia, Sweden, and France) by three researchers involved in the main project. Participants were recruited through a free voluntary invitation to participate in the study. The invitation was distributed by the researchers involved in the project (the authors each conducted at least one interview).

In this study, six children of different ages participated, which is presented in Table 1, together with data on how much time they spent playing Minecraft, for how long they had played, where they played, and what hardware they used. The participants were recruited according to the criteria of following the development of Minecraft use at different ages. All children had used Minecraft regularly, with varying levels of expertise, and had also played other video games (such as Super Mario). The children represent the normal use of Minecraft at their age, considering we found the sample in multiple contexts. According to online data [42], Minecraft has over 140 million monthly active players in 2023. COVID-19

had a significant impact on Minecraft, as the number of active players increased by over 14 million from 2020 to 2021. The game has attracted a diverse group of players ranging from young children (as young as 3 years old, even though the game is recommended for 7+), to adults.

Table 1. The participant data concerning the play of Minecraft at the moment of the interview.

ID	Gender	Age	Country	Duration	Time/Day	Where/When	Hardware
7a	Boy	7	Italy	2 years	>1 h	Living room/ afternoon	Ipad
11a	Boy 1	11	Croatia	4 years	30 min	Bedroom/ evening	Ipad, mobile phone, PlayStation
11b	Boy 2	11	Croatia	4 years	1–2 h	Parents' room/ evening weekends	Computer
15a	Boy 1	15	Croatia	7 years	1–2 h	Bedroom/ afternoon	Computer
15b	Boy 2	15	France	4 years	>1 h	Bedroom/ later at night	Computer
18a	Boy	18	Sweden	10 years	2 h	Bedroom/ evenings	Computer

Furthermore, the sample reflects the preference of boys to play Minecraft. In fact, according to the same statistical data [42], Minecraft has more male players than female players. Up to 54% of the boys aged 3 to 12 play Minecraft. This compares to only 46% of the girls in the same age group. The gap widens when looking at the age group of 6–8. A total of 68% of boys aged 6–8 play Minecraft. Only 32% of the girls in the same age group play Minecraft. Thus, Minecraft attracts males as its primary user demographic.

Data was collected through semi-structured interviews using the prepared interview protocol (Appendix A). The interviews were conducted in the children's mother tongue and took place in their home environment. The interviews were audio recorded and then transcribed verbatim and translated into English. The transcripts were then read through several times by the three researchers to obtain an overall picture of the content.

This study respected the children's anonymity, privacy, and ethical implications. All data was stored in a university database, and it will be destroyed after 3 years.

3.2. Thematic Analysis of the Interviews

In this study, a thematic analysis was carried out, which involved comparing information from the interviews to identify patterns and common themes. The thematic analysis used an inductive approach as outlined by Braun and Clark [43], in which the analytical process involved six steps. The first step was to become familiar with the entire set of data, i.e., transcribing the interviews and reading the transcripts several times. The next step was to code the transcripts and systematically divide them into units. This involved detecting patterns in the ways Minecraft acts as a BO for children's learning of science and SD, and how Minecraft acts as a BO for children's relationship with physical and virtual nature. Our definition of Minecraft as a BO was analytical for the purposes of this research. Indeed, the definition of BO was used to trace the characteristics of Minecraft and to shed light on its use in children's practices. Furthermore, the use of Minecraft as a BO emerged from the data analysis and interpretation of the researchers and was not designed by a teacher as an activity specifically aimed at using Minecraft as a BO. In the following step, similarities and differences between the coded units were examined, from which preliminary themes were organized. Excerpts relevant to each theme were then selected. The next step was to review the themes of the selected excerpts and the themes of the whole data set. After this,

the characteristics of each theme were then defined, and each theme was named. In the last step, excerpts were selected that represented each theme.

Table 2 shows the identified themes and the sub-themes. The first two themes give us information to answer the research question about children's relationship with physical and virtual nature; the next two themes focus on Minecraft as a BO for children's learning of science and SD.

Table 2. Identified themes and sub-themes.

Theme	Sub-Theme	Example
Activities	Real vs. virtual • Fly/mining • Endless activities/no limits of space, time, resources • Adventure (kill zombies, travel/move)	*You can build something in an hour or two, you can fly, you can take something from nowhere. (Boy 1, 15 y)*
Context	Real vs. virtual • Tree to recognize and use • Fantasy animals to meet • Real animals interact	*Sheep, cows, wolves, foxes, and later parrots were added. (Boy 2, 11 y)*
Content	Science vs. fantasy • Seasons • Minerals • Processes	*From ore, you can make some armor, some other ores are essential for making machines, or so. (Boy 2, 15 y)*
Value	Practical vs. aesthetic • Pleasure to be • Pleasure to manipulate	*You can build a house, you can make tools and weapons. You can really make a lot from trees. (Boy 1, 11 y)*

4. Results

The results are presented and organized based on the four identified themes, namely, activities, context, content, and value, in order to answer the two research questions: (a) In what ways may Minecraft act as a boundary object between children's formal and informal learning of science and sustainable development? (b) In what ways may Minecraft act as a boundary object when children build relationships with nature? The following sections explore the identified themes as four dimensions, together with corresponding excerpts from the interviews.

4.1. Activities: Real versus Virtual

The children agreed that Minecraft allowed them to do any activities they liked to experience. The more activities they did, the more there was to do.

- I like it because it has endless possibilities of building, and you can express yourself in a very creative way in the game. (Boy 1, 15 y)
- It is a proceedingly generated world which makes it exciting to explore. (Boy, 18 y)

This is a particular feature of Minecraft, different from video games: in video games, when you explore all the possible paths, and you reach the end, you stop playing. The social dimension is also a feature they like, but it was not always possible due to the restriction of video games or parental control.

- I like it because of the possibility of playing it as multiplayer and because of the graphics. Also, I like it because it is not a classic shooting game, but you can build something, fight against zombies, etc. (Boy 2, 15 y)

The children compared their experiences with common video games, such as fighting with zombies.

- I like it because I can build and fight against zombies. Also, I like it because I can play it with my friends. When I play it alone, it is boring. (Boy 2, 11 y)
- I like to build houses and look and excavate the ore and diamonds, fighting against zombies. (Boy 2, 15 y)

Also, the main activity that all students liked to do was, of course, mining, which gives Minecraft a specific place in the gaming world. To the young players, the flying activities are also a specific game experience, which they compared with what is possible to do in real-world activities, such as experiencing gravity or not being able to excavate stones and make blocks.

- Definitely, you can not fly. Also, you can not make a stone block, you can not excavate stones and make blocks, or you can not break the trees. (Boy 1, 11 y)
- I like to fly. And there is no gravity. (Boy 1, 15 y)

The ludic side of the play stays dominant: to move, to explore, to travel:

- I like it for adventures. The thousands of buildings. And because there are many maps to venture into. What I can do in Minecraft that I can't really do is I can build a lot. Easily explore new worlds and more! (Boy, 7 y)
- Mostly, I like to build structures and machines. (Boy 2, 15 y)

4.2. Context: Real versus Virtual

The regular environment in Minecraft is appreciated and the participants recognized the nature in the game as similar to real nature, e.g., different biomes, animals, and trees.

- There is a nature in Minecraft. I think almost the whole world in Minecraft is nature. Especially when there is a village, then around is nature, like sea, beaches, woods, there are different types of woods, then there are swamps, etc. (Boy 2, 11 y)
- The whole game is in nature. (Boy 1, 15 y)

And they could recognize the types of trees, like birch and oak:

- In Minecraft there are many trees but the only one I can recognize is the fir. . . the pine. (Boy, 7 y)
- Birch, oak, and pine. (Boy 2, 11 y)
- Pine, trees from the savannah, oak similar tree. (Boy 2, 15 y)

The children appreciated the opportunity to see and experience something new in Minecraft, such as interacting with specific animals. For example, the child in the following excerpt expressed that he likes the dolphins in Minecraft, and it was only after some time that he experienced them in real life for the first time.

- Dolphins, once during the summer holidays, we went on a boat trip and saw dolphins. (Boy 2, 11 y)

The other children also presented different animals they had experienced in Minecraft, such as turtles, horses, cows, wolves, foxes, polar bears, parrots, and rabbits.

- Sheep, cows, dolphins, turtles, tropical fishes, polar bears, chickens. (Boy 1, 11 y)
- Sheep, cows, wolves, foxes, and later parrots were added. (Boy 2, 11 y)

The children also experience different biomes like the desert.

- I have only learned how, e.g., what a desert looks like. (Boy 1, 15 y)

The oldest participant, who had been playing Minecraft for many years, expressed his experience of the context and the connection between virtual and real nature.

- There are several different species and biomes that are the same as in real life. [. . .] I have learned more about what there is in the ground for example that there are caves and minerals that can be mined and used for producing different things. I have also learned about plants such as their names and what they can be used for. [. . .] you must be careful of having animals in the right place so that they get food and survive, otherwise, you won't survive. (Boy, 18 y)

Some of the children made a distinction between real and virtual nature in terms of their relationship with animals and biomes:

- There are many animals, some are monsters that don't really exist. You can ride, for example, horses. But there is also another mode of animals, other animals that are not real, like skeleton horses and much more. My favorite animals in Minecraft are horses, but I've never interacted with them in real life. In Minecraft, there are various environments. I explored nature; For example, the deserts; the woods. What I can't do in reality, what I can do in Minecraft, is that I can see everything in squares and go into environments that I've never actually seen before. (Boy, 7 y)
- You can get food, ride a horse, use the wolf as a protection if you tame it. [. . .] But no, I have never seen them, not even in the ZOO. (Boy 2, 15 y)

4.3. Content: Science versus Fantasy

The data indicate that children learn science content as they explore the fantasy world of Minecraft. The children become familiar with simple facts, such as nature changes as you move in latitude and longitude.

- Nature changes only if you walk to the other location, then, nature is different (like woods, grass, animals, etc.). (Boy 1, 11 y)
- Nature in Minecraft is involved in making things a little more realistic. Nature does not change according to the seasons but according to the places where they are. (Boy, 7 y)
- There are no season changes in the one and same biome, but there are differences between the biomes such as snow in some and summer in others. (Boy, 18 y)

The data also shows that the children had a strong relationship with minerals. All children spent a lot of time playing Minecraft discovering and understanding minerals, such as rocks, diamonds, emeralds, ores, and granite.

- I learned a lot. I learned that the diamond is the hardest mineral in the world. Yes, I used some sticks, like in Minecraft. In school, I learned about obsidian and diamond. (Boy 1, 11 y)
- Long time ago, at the beginning of playing, I learned that diamonds are the hardest rock. (Boy 1, 15 y)
- Quartz, block of magnesium, diamonds, copper, iron, emeralds, and dripstone. [. . .] From ore you can make armor, some other ores are important for making machines (Boy 2, 15 y).
- Well, diamond is a strong material that can be used for certain things where strength and solidity are important, and gold is softer and less heavy than iron. And copper conducts current. (Boy, 18 y)

And some processes involving materials are connected to reality.

- [. . .] charcoal can be produced from trees. (Boy, 18 y)
- The sudden cooling of lava gives you obsidian. However, I saw that process in Minecraft, but I didn't know about it. Later, when we learned about it in school, I was able to easily relate it to Minecraft, as I saw it already. Similarly, I just saw obsidian in Minecraft, I didn't know more about it. But in school, when we learned about obsidian, I already knew about the term because I saw it in Minecraft. The same is with granite. (Boy 1, 15 y)

The data indicate that the children learned science content, such as different biomes, animals, and trees, that can be related to sustainability issues. For example, understanding the importance of plants to life on our planet and the different food chains that depend on them.

- I have also learned about plants such as their names and what they can be used for. For example, it is necessary to have grass otherwise the animals such as cows, sheep, and pigs won't evolve and then they will not produce milk, wool, or meat which is necessary for being able to survive. [. . .] Sometimes you can experience photosynthesis.

Plants need water to be able to survive. Most animals can only exist where there is food and for instance grass. (Boy, 18 y)

In addition, Minecraft helped the children to recognize the impact that humans have on nature and how this can have destructive effects.

- Nature is changing, especially if you destroy it. And nature changes only under the influence of people. You can destroy trees, you can excavate something, you can make flat terrain. (Boy 2, 11 y)

4.4. Value: Practical versus Aesthetic

Children's experiences of Minecraft can be considered based on both the practical and aesthetic values that the game provides. Some of the children simply appreciated being in nature and also appreciated that there was no pollution in Minecraft. The aesthetic values were present in these cases.

- I like to be in nature and build something with a natural theme (like houses or castles). For example, if I build a castle, I build it overgrown to merge with nature. (Boy 2, 15 y)
- I like to be in nature more than in the settlement. (Boy 1, 11 y)

Some of the children highlighted the interplay between play and real-life preferences, where the value of being able to take on practical tasks and solve problems was emphasized.

- I like it most because of surviving; you can build something, and it is almost like real life. It is so detailed I like to survive, collecting materials. I don't build so much, but more collect materials and play with them to survive. (Boy1, 11 y)
- I used parrots as a pet and used cows and sheep to get food. (Boy 1, 15 y)

The ludic dimension was also present in the manipulation of nature on the surface in terms of both practical and aesthetic values.

- You can excavate the rock, and then you get a stone, and then you can build the house, some tool, or weapon. (Boy 1, 11 y)
- Structures and buildings are fun to create. [...] You can also build things that you can't do in real life, which makes you more creative and you can also use imaginary materials. (Boy, 18 y)

Some children also expressed the ludic dimension in manipulating nature, such as the seasons or biomes, by changing structural aspects of the game, such as installing modules that extended the game.

- You can install different modules (e.g., summer, autumn, winter, spring), and then nature is changing. E.g., leaves fall, or animals hibernate during the winter or so. (Boy 2, 15 y)
- There is grass on the ground and flowers. But it could be developed with some modules (e.g., to add a thicket). (Boy 1, 15 y)

5. Discussion

In the following subsection, the four dimensions that emerged in this exploratory case study—activity, context, content, and value—are analyzed and discussed in relation to the role of Minecraft as a BO. Furthermore, in the last section, the implications of adopting this analytical perspective to analyze Minecraft as a BO is extended for improving educational practices.

5.1. Minecraft Acts as a Hybrid BO

In terms of real vs. virtual activities, it is clear that Minecraft offers the opportunity to move around a lot in nature, while at the same time sitting still in a chair in the bedroom or living room. For example, one modality that children use to explore the environment and discover "other-than-me" is touch. Touch is a concept developed and used in philosophy, for example, by Merleau-Ponty [44]. According to the philosopher Nancy [45], touch is a

sensation and a feeling. This contact reduces the distances of "in-between": information is transmitted in the act of tactile interaction, translating sensation into meaning. In Minecraft, for example, touch is the activity of mining.

In terms of real nature vs. virtual context, temporal and spatial conditions can be explored thanks to Minecraft. For example, in terms of interacting with different animals, we can see that children's experiences with Minecraft helped them to become aware of animals that they had never met in real life. Furthermore, when they had the opportunity to see the animal in real life, they already knew the animal and had a boundary to it. The children expressed that seeing horses, cows, and other animals in the virtual environment was nice and made them happy. There was an agentic attitude among the children to explore new environments and interact with specific animals online. It is interesting that the children did not make the comparison between the virtual and the natural environment, they adapted to the contexts, even though the possibilities for action were different. This could be seen as different from the adult-centered perspective.

In terms of the science vs. fantasy content, playing Minecraft allowed the children to become familiar with science content knowledge, such as the characteristics of changing seasons, food chains, animal and plant species, and awareness of changes in nature. In Minecraft, this knowledge also included managing resources, such as materials and food to survive; planning and organizing building projects; spatial awareness to manipulate and visualize three-dimensional spaces; problem-solving and critical-thinking skills when building; and adapting to challenges and changes in the biomes.

There is an interplay between technical manipulation for its own sake (to survive or continue exploration) and the aesthetic values of preferences. Games like Minecraft may be attractive because they give children a form of creative agency in using infinite resources to reconfigure a new digital object [46].

In conclusion, in light of the analysis carried out, we consider Minecraft to be a hybrid BO because it gives space and hosts the continuity between digital and non-digital, which is blurred [38] by the agentic and creative engagement in finding a solution. Technical skills are used and developed in the process. Minecraft is open to the external and the real, finding representations in the virtual environment and vice versa. This activity around the games could be interpreted as "post-digital play" [47] to stay in touch with the game when not concretely in the game.

Moreover, there is a possible link between informal and formal learning, where children's virtual making could be a ground for activating digital literacy, as already explored by Deuzanni [17], and also for activating interest in science and SD [6]. Children's pragmatic use of the content, also highlighted by [48], becomes the driving force to learn more about the context where they are asked to solve the problems at hand in order to survive in the Minecraft environment. This type of experience directs children's interest toward the need to understand scientific phenomena such as biodiversity, ecological systems, and changes in nature. As previously stated by Driver et al. [14], teachers should be aware of children's experiences from this type of informal learning context and take these experiences into account when planning lessons in the formal classroom context.

Finally, the link between children's agency in the making [49] and ESD [46] is established through exploring virtual reality in relation to nature. The underlying issues of SD in the game open an urgent request for action and active involvement in the defence of the natural environment such as taking care of plants, feeding animals, and not destroying nature. Thus, specific reflections have emerged concerning the agency of learners, which some describe as the "ownership" that students experience in their learning process and their involvement and identity formation as learners in relation to others [23]. In playing Minecraft, children may be promoted as critical actors, and as previously suggested by Mondada [24], there is a need for new ways of letting children approach science and sustainability issues, and we suggest that playing Minecraft could be one of these new ways. As discussed in the next section, we extended our reflections to how the features of Minecraft as a BO could be activated for educational purposes.

5.2. Minecraft as a BO: Implications for STEM Education

In this study, we explored Minecraft as a BO between children's formal and informal learning about science and SD, and as a BO when children build relationships with nature. We consider that the features explored are possibilities that need to be actually used in practice to turn the Minecraft game into an operational BO.

In terms of STEM teaching, virtual making in Minecraft is suggested as grounds for promoting children's learning of science content, and for promoting children's interest concerning sustainability issues that can also shape their agency in the natural world. In this sense, using Minecraft as a BO would increase the possibility of coming across pieces of knowledge that would otherwise be inaccessible or hindered by disaffection in STEM-related content.

As previously described by De Freitas and Palmer [5], children make sense of their environment through play. When playing Minecraft, children's "seriousness" in solving problems in Minecraft's natural environment leads them to explore materials, species, biomes, and other aspects of nature that could be of interest in relation to formal learning contexts if considering the disaffection children hold against STEM-related learning. Previous research in science education suggested that children make sense of their everyday experiences by building mental representations that they later use to understand scientific phenomena in a classroom context [7,8]. This implies that an awareness of children's prior understandings is necessary in order to organize teaching that promotes children's learning in science [7]. Today, it is important to understand how new digital technologies create new cultural conditions for children's development [2], and how this affects the way children understand scientific phenomena and situations in the natural world. Therefore, it is necessary to recognize an understanding of children's everyday lives based on the use of technology [15].

Today, children spend more time indoors than previous generations and their everyday lives include the virtual worlds of computer games, such as Minecraft. This combination affects the way children experience the natural world, which, in turn, affects their learning experiences in the science classroom. This study shows that in the Minecraft context, the children gain a range of everyday experiences related to scientific phenomena and sustainability, that they are likely to bring into the classroom context. As mentioned above, the issues of SD call for teaching that promotes children's interest and understanding of scientific phenomena. This study showed that in the virtual world of Minecraft, children experienced ecological systems, including different types of plants and animals, as well as different biomes. The findings indicate that children merged their experiences in the virtual world with their experiences in the physical world. In this sense, Minecraft contains science and sustainability content that crosses the boundary between the virtual world and reality. This is in line with what Deuze [38] previously suggested about children's construction of embodied practices that bridge the physical and virtual worlds. In this way, we suggest that Minecraft bridges children's physical and virtual relationships with nature, that is, Minecraft becomes a BO that provides children the opportunities to come across pieces of knowledge that they have not otherwise been able to experience.

To conclude, children use and process knowledge and information from everyday experiences that are different from previous generations. That is, they understand the natural world both from experiences in virtual worlds such as Minecraft, and from experiences in the physical world. In STEM education, it is therefore crucial to consider children's experiences in both the virtual and the physical worlds in order to provide the best learning opportunities. This implies, being aware of the learning opportunities that digital games such as Minecraft can provide, and understanding Minecraft as a BO that bridges the virtual and the physical world.

5.3. Limitations of the Study

In this exploratory case study, semi-structured interviews were conducted with six children. This means that the sample size in the study was not sufficient for quantitative

analysis and to make a strong claim about the theorization of Minecraft as a BO. However, we highlight how the in-depth focus enabled rich data to be collected and analyzed in detail and suggest that the emerging phenomena may not have been captured by larger studies. Further, the study only included boys. However, due to the predominant distribution of children's use of the game, the sample respected the representation of the users of the game. Future research should consider a quantitative approach to gain a broader perspective on the impact of children's use of Minecraft on science and SD learning. Also, new methodological approaches are invited to capture the complexity of children's post-play from a child's perspective, rather than just an adult's.

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Appendix A

Time
How long have you been playing Minecraft?
How many hours?
Where do you play and when?
Like
What do you like about Minecraft?
What do you like to do in M?
What you can do in M that you cannot do in a real place?
Nature
What about nature in M? Do you like staying in the nature of M?
Nature changes in M or it is always the same?
Minerals
Which kind of minerals are there in M?
Did you discover something about the minerals?
What you can do with them in M?
Vegetation
Are there trees in M?
What types of trees do you know in Minecraft?
What can you do with the trees in M?
Animals
Are there any animals in Minecraft?
If so, which ones?
What can you do with the animals in M?
Which animal do you like best in M?
Have you ever interacted with that animal in real life?
Formal Learning
What do you think have you learned new in M?
And about nature?
Do you like the idea to use M in the classroom?
Informal Learning

Did you explore something in nature outside thanks to the M?
What can you do in M that you cannot do in reality?
Have you ever used something discovered in M in other contexts? (talking with friends, in family, to do some activities, etc. . ..)

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