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AN ETHNOMATHEMATICAL STUDY OF PLAY IN MINECRAFT

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This paper explores how children engaged in playing Minecraft in an afterschool program develop mathematical approaches in their in-game activities. The investigation is framed as ethnomathematical in the sense that, rather than searching for specific curricular concepts, it explores the problem situations and explanatory systems that children develop. Aesthetics, symmetry, collaboration, copying, and efficient building strategies all lead to local problem-solving and explanatory systems and can therefore be characterised as steps towards ethnomathematics. In the explored example, collaboration between the children and the afterschool program's attitude towards children's collaborative gaming are crucial factors in the way Minecraft supports the development of mathematical thinking.

Keywords: Ethnomathematics, Game based learning, Minecraft.

INTRODUCTION: MINECRAFT AS CHILD CULTURE AND EDUCATIONAL DREAM

Minecraft is a widespread phenomenon, with more than 13 million individual purchases of the game. There have been several attempts by educators to use Minecraft in formal mathematics teaching (Miller, 2012; see also www.minecraftedu.com), and the Lego-like block structures are sometimes identified as a reason for Minecraft being well suited for mathematics education. In this paper we aim at providing empirical knowledge which might inform such claims, by exploring the mathematical aspects of activities engaged in by children playing Minecraft.

Minecraft can be played alone or with others on a local area network or as a massively multiplayer online game. The Minecraft world consists of one meter cubic blocks, generated in a world to create landscapes that may include mountains, meadows, deserts, lakes, and oceans. In the game, you can break, collect, and place the blocks, using them to construct buildings and landscapes or transforming them into other materials or tools. However, playing Minecraft is not a well-defined and uniform activity. With its open-world gameplay, the game itself allows players to design not only their physical surroundings but also their own narratives - for example, surviving in a world with limited food resources, going on adventures, building huge castles, or brewing potions that enable one to fly (Duncan, 2011). For teaching purposes, there is also an educational version called 'MinecraftEdu', which is a modification of the original game that allows for a more controlled game environment, in which teachers can prepare lessons and can more easily follow students' activities. The game is typically used as a replacement for concrete materials when children are to work with areas, volumes, ratios, scale, histograms, and types of graphs. Children's gaming activities are not included as activities in these learning resources, nor is the premise that the children are present in the virtual world taken into account (Miller, 2012).

QUESTION

The data presented in this paper were collected during a project that explored the question, “What mathematics do children use and develop when they play Minecraft in an afterschool program?” (Køhrsen, 2013). In this paper, we look for situations that can be considered mathematical, in the sense that systematic approaches are applied or problems are addressed, and we ask what situations may be characterised as mathematical in children’s free time play with Minecraft.

THEORY

According to d’Ambrosio (2001), different cultures, including nationalities, tribes, genders, organisations, and professions, develop knowledge systems and problem-solving strategies that can be understood as parallel to those of western mathematics, and should be recognized as such. In line with Devlin (2011), we also understand children’s gaming culture as a legitimate culture, where mathematics activities and problem solving may occur.

In our research, we are looking for situations that can help to clarify whether children’s activities when playing Minecraft foster a unique ethnomathematics, and how it might be characterised (d’Ambrosio, 2001). Any such investigation of children’s gaming culture, as a legitimate culture in which an ethnomathematics can be developed, is likely to encounter the problem of recognising a mathematics that differs from scholastic mathematics (Millroy, 1991). Bishop (1997) offers a framework in which mathematics can be analysed as a cultural phenomenon, offering a way of recognising core mathematical activities as part of the culture in their own right.

In his analysis of mathematics as a cultural phenomenon, in which he searches for mathematical similarities, Bishop describes six forms of activity that seem to occur across all cultures.

1. Counting - referring both to the development of number systems and to actions around counting (for instance, using objects to support counting);
2. Locating - referring to different ways of coding and symbolising special environments, and to different ways of describing and understanding physical space and/or objects in space;
3. Measuring - referring both to the words used to describe different measurements and to the tools or body parts used for measuring;
4. Designing - referring to the development from imagined form and shape and to the reshaping of the environment;
5. Playing - both strategic games and gambling games;
6. Explaining - where questions and answers are part of extending human cognition beyond experience and environment (Bishop, 1997).

Following Bishop, the aim of this paper is to find and describe examples of mathematical situations and activities in children's informal play and construction work in Minecraft. We would expect such situations to provide relevant focal points for an empirically based understanding of the systems and problem-solving strategies constituting a Minecraft ethnomathematics.

METHOD

An ethnographic methodology was employed to investigate this question. This mend, that rather than describing and analysing the children's products or measuring their conceptions or competencies, we attempted to gain access to their practice and culture in a longer term way. This was done with a view to developing a holistic description of the mathematical activities that these children engage in and how these activities are contextualised when they play Minecraft in an afterschool program (Hastrup, 2010).

To this end, we followed seven 10-year-old boys over a period of three weeks as they played Minecraft in their afterschool program. They were selected on the basis of availability and high levels of gaming activity. In this particular program, playing Minecraft was mainly a boys' activity, and no girls were available who met these criteria. The data collected include interviews, hand-held camera recordings of situations where Minecraft is played, and observations (field notes). The video data were analysed in three steps: first, the events captured on video were summarised in written form (with time codes); second, using Bishops framework, the mathematical aspects of Minecraft play were summarised; and third, two cases where children perform activities that we interpret as mathematical were fully transcribed and analysed in depth (Rønholt, Holgersen, Fink-Jensen & Nielsen 2003).

The interviews were video-recorded, comprising an oral record of the child's relation to the game and an action record based on the strategies and preferences observed during gameplay. The oral part of the interviews was transcribed, and action reports were compiled for each sub-question.

FINDINGS AND ANALYSIS

This section is presented in three parts. First, the context of the findings is described by describing the gaming culture of the afterschool program; second, a range of examples is given of mathematical constructions in the children's gameplay; and finally, the analysis of findings, using Bishop's categories of mathematics activities, is presented.

Context for mathematical actions in Minecraft

Observations during the afterschool program showed that the program endorse that children play computer games, and that the physical environment enabled friends to play these games together. In the interviews, the children explained that they play less at home than in the afterschool program. They also explained that gameplay in the afterschool program tends to involve larger constructions and longer-lasting games than when they play at home. This highlights the fact that the findings from this study are bound to these specific players in this specific context. Here, when the children played Minecraft, they often played together in larger groups, over an extended timespan of days or weeks. During such games, large constructions were often built by collaborating and working for several days towards a certain goal - for instance, to finish a bridge or a castle. In the observed games, these large constructions were demanding to construct as the children took account of both symmetry and proportions.

Mathematical activities

The mathematics-related activities that we found in the children's play fell into several categories. These included construction activities involving symmetries, geometric reflections, approximations of round shapes in a cubic virtual environment, and decorative patterns; activities involving mining, including the use of compound numbers when referring to large amounts of a material (e.g. 'don't stop [digging] until you have at least two times 64 iron [blocks]'); and ways of finding materials and navigating through the mines. In this section, we will elaborate on the mathematics and methods used when constructing, and on the acquisition of new knowledge about construction. The data include many more observed examples of mathematical activity, but here we will focus solely on the activities around constructing because construction is the dominant form of activity in the game.

Designing houses: All the houses built by the children used three blocks (3 meters in game scale) from ground to ceiling. Since an avatar in the game is 1.7 meters in game scale, it is possible to enter a building that has a height of only two blocks. The children explained the chosen height by saying that it "looks right", and that inside it they can jump, which would not be possible in a house with a height of only two blocks.

Symmetry: This matters when constructing a house, and the children spent a lot of time making patterns and other adornments. The houses, which tended to imitate family houses, were clearly designed with an understanding of symmetry, as the children explained that where they placed doors and windows was not coincidental or random. In one example, where three children built a house together, the width of the house was adjusted to accommodate three windows of equal size on one side, equidistant to each other. The colour of the house's corner pillars differed from that of the walls, making it possible to develop a pattern with one block between each window on both the interior and exterior of the structure.

The only observed quadratic house was built at the top of a tree, using the crown of the tree as a guide to measurement to ensure a perfect quadratic form for the pyramidal roof, and to ensure that the roof would require only one block rather than four at its highest point. In fact, oak trees in Minecraft have a quadratic crown of an odd side length. The boy in question didn't seem to know that, but explained that he could not build a house with only one block at its peak without using an oak tree for guidance.

Interior decoration: In most of the constructions observed, the children devoted a lot of time to interior design. In one case, three boys built a house together, in four storeys, with an internal measurement of 3 x 7 game scale meters. Each storey had its own purpose (processing of materials, keeping valuable materials, keeping other materials and tools, and a sleeping quarters). In the middle of one of the gables, a ladder connected all the floors of the house. Each storey was decorated along two axes of symmetry, shown in Figure 1 left. The figure shows the floor plans of the sleeping quarters. The room needs a bed and a coffin to be in perfect symmetry; one of the children mentioned this, saying that he hoped a new player would join their game so that the sleeping quarter could be completed.

Construction of castles and circles: Unlike the houses, the children used different rules for the choice of height in other buildings, such as castles, which generally have a larger height from floor to ceiling. When asked, the children did not have exact words for the proportional relation between the ground and the height of the castle, except to say that it just "looks right". In effect, this means that a castle may have a height of ten blocks to the roof, as compared to the three blocks used for houses.

The castles provided a few examples of approximations of round towers. Not all the children succeeded in building round towers, and when asked most would build a quadratic shaped tower diagonal to the game grit instead (Figure 1, top right). The children could see that this shape was not round, but could not see what needed to be changed. One child learned to use approximate circle shapes (Figure 1, bottom right) by copying the shape, block by block, from another child. A third child had knowledge of how to construct two sizes of a circle, but he could not apply that knowledge to construct circles of other radiuses.

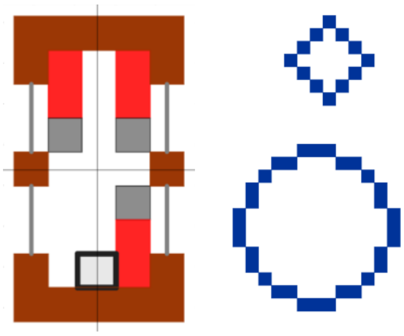

Figure 1: Symmetry in design of house interior (left), diamond shape (top right) and approximated circle shape used to construct round towers (bottom right).

The propagation of strategies for the construction of circle shapes is one example of knowledge sharing and sharing of strategy, and of the need to learn new things.

Constructions of known measures: Certain constructions in the game require exact measurements. This provides other challenges beyond constructing on the basis of aesthetics or the approximation of sizes and shapes. One example of this was seen in the construction of a fountain. Based on his knowledge of how far water falls from a water source, the child knew the radius of the fountain but not the circumference. This led him first to place tree blocks on top of each other to form the centre of the fountain; then, from the centre he counted the radius of the fountain in four directions, placing a block each time, and completing the circumference by connecting the four blocks.

Bridge structures: Minecraft generates worlds with mountains, ravines, valleys, and lakes, requiring the children to construct bridges. In the next example, a group of children constructed a series of bridges between mountain peaks. When two bridges met in the air, two approaches were used to determine how they should intersect. One method was to ensure that the bridges were at the same height. The children did this by using the avatar's ability to fly without changing altitude to measure the correct height, placing the head of their avatar at the same height as a bridge and then flying in a straight line required for the bridge. The other approach involved creating a suspension bridge with stairs at both ends, adjusting the height by creating the necessary steps at each side. In this second approach, however, the children expressed concerns about their wish to have identical stairs at each end of the bridge.

Construction methods: The game player's perspective created an extra challenge for the children in their desire for identical or mirroring constructions because it is impossible to see the construction being mirrored while building the new one. In this section, two observed methods will be examined in more detail: a 'trial and error method' and a method that involves copying by memorising segments of a larger construction.

In one example of 'trial and error', a child was attempting to build a spiral staircase in an approximate round tower. His strategy can be described as continuous adjustment by correcting an ongoing construction, but it also indicates a realisation that certain strategies were not working, as he started again from scratch with the knowledge acquired without yet having a plan for the construction as a whole.

- First he attempted to create steps in a straight line. Every step has a left edge and a depth of one block; when he reached the first corridor where he had to turn, he realised that his strategy did not work and made attempts to adjust the steps to follow the turn (Figure 2, left).
- After the turn, he continued with a strategy in which every new block in forward direction was a block higher than the previous one. At the next turn, this led to further problems (Figure 2, left), and he decided to remove the whole staircase and start over.
- This time, he started a little closer to the turn. He kept a straight left edge on the stair while attempting to build the staircase up in height to fit the turn. Afterwards, he investigated the construction, and adjusted the steps (Figure 2, right).

- As seen on the right in Figure 2, the adjusted step causes him to start again a bit lower down the staircase, adjusting the steps at the beginning of the staircase to accommodate the new knowledge obtained.

Figure 2: first attempt to create a spiral staircase (left), and the process of readjusting the staircase (right).

In this case, the boy explained that he was not sure how the stairs was going to look like, and that he was experimenting to find a strategy for building the staircase.

In an example of the second method (copying by memorising segments of a larger construction), another boy wanted to copy the approximated round tower and its spiral staircase. It was not possible for him to see the staircase he was copying when building, and he had to not only turn his head, but run across to another tower to investigate the construction he was copying. Given the complexity of the construction, it was not possible for him to memorise it in its entirety. As he started to copy the stair, the boy memorised how many blocks would be required for a given step. Memorising each step would take some time, counting while focusing on one block at a time, making it possible for him to memorise two or three steps at once (Figure 3). After building the steps, he could not be sure whether or not it was correctly built, running one more time to check. Searching for a more effective method, the boy discovered a three step pattern in the steps, which he continued, calling it 'One-One-Tee' as a reference to the shape of the steps (Figure 3). The use of segment names made the construction of the rest of the staircase much faster, in the end enabling the boy to repeat the pattern four times without checking the original construction.

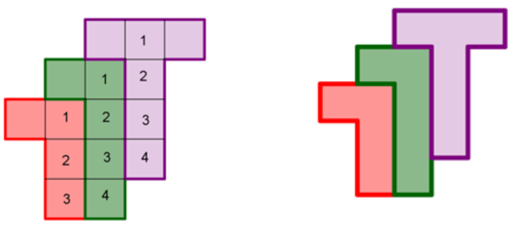

Figure 3: Method of memorising by counting blocks on each step (left), and method of memorising segments 'One-One-Tee' (right).

Table 1

Findings relating to Bishop's categories

Category	Example	Analysis
Counting	Mining	Counting objects occurs regularly in the game. Because of the game design the player has a maximum number of items they can hold in each slot. A new form of compound number is used when talking about huge amounts: 64 for 'many', counting by saying *2 times 64* as opposed to 128, or *more than 64* to signify a lot of an item, giving 64 the same function as 100 in normal use.
Measuring	Fountain & bridge building	Two aspects of measuring become clear from these data. When constructing objects of specific size, the children tend to measure objects as an area, or in terms of the width of the empty space between the blocks. They have an idea of the empty space in the middle, but not of the outer length or of the number of blocks necessary to build the object, and use the empty space to create the rest of the construction. When connecting bridges or building outer walls of castles and other huge or tall buildings, altitudes are measured by use of the in-game ability to fly at an unchanging level.
Locating	Construction of circles, bridges	In the many collaborative construction projects, visual block design is used to explain the construction process. Words are used to locate and describe objects or placement of single building blocks, along with use of the cubic design.
Designing	Houses, castles, bridges	Altering of landscape and constructions is a key game feature in Minecraft, so that designing is a common activity in the observed games. The children's culture of the afterschool program favoured huge constructions such as castles and extra detail, making these important aspects of designing. Symmetry and recurring design elements were part of almost every observed construction. Unlike Lego, the game design challenges the design process by making it impossible for the player to see anything other than the immediate area they are building, requiring the children to develop strategies for remembering construction parts and design patterns.
Explaining	Spiral staircase,	Explaining is one of the social norms in the group. Constructing together demands language and ways of

	build a circle, collaboration	telling and showing to explain different methods of construction, usually involving a high degree of showing to provide visual support for words of location and amounts of different blocks used.
Playing	As the frame is a game in itself, and no specific game or play activities were observed within the game, there is no analysis under this heading	

CONCLUSIONS

The mathematical actions discovered in the investigation are influenced both by the design of the game and the social and cultural conditions in the afterschool program. The game challenges the children to visualise and systematise constructions, as they try to realise their desire for unity, symmetry and aesthetics. New constructions and construction methods are learned from other children, by showing and telling as well as through trial and error. Demanding constructions originate from the children’s own game narratives, which they often develop in groups and in admiration of each other’s work.

The game culture in the club differs from the children’s experience of playing alone at home, influencing the complexity of the children's constructions, their collaboration and knowledge sharing. The children explain that if they play at home, they create smaller constructions, and they create them alone. If they lack the knowhow to create specific constructions they wish to build, they use the Internet but are limited by having to comprehend English. In this manner, the after school program is where Minecraft itself becomes a place for shared actions and mutual challenges, impacting both on what is played and how it is played.

Two aspects of the game’s design play a central role in providing challenges for the children’s construction activities. The game’s first-person perspective means that the player can see only that part of their construction that is directly in front of them. In relation to their idealised forms for identical staircases, towers, and so on, it means that the children cannot see the construction they are mirroring or copying while building. They are therefore forced to develop strategies in how to memorise the original construction, and this mediation of their actions changes the premise for construction in relation to, for example, working with building blocks.

Because the game only features three-dimensional cubic elements or blocks, it is impossible to construct circles, lines and points. When the children compare widths, they often describe the width as the distance between the two outer lines of the blocks. This is problematic when, for example, determining the number of blocks needed for a construction with an inner spacing of 2 x 3, where the perimeter of the structure has a size in itself, going against their school knowledge of perimeters as having zero size. Building with cubes also changes how the children construct a circle, which is a difficult shape that has to be learned.

In conclusion, it is worth reflecting on whether these data constitute evidence of an actual ethnomathematics, in line with d'Ambrosio's (1985) descriptions of distinctive mathematical actions of indigenous people. This question is not easily answered. If Minecraft-mathematics is to be seen as an ethnomathematics, it is because it mediates the children's actions, requiring problems to be solved in a different way than in the surrounding reality. It remains an open question whether the observed methods and systemisation constitute a coherent mathematical approach to the Minecraft world, or whether they are merely fragments of various approaches used by different children in different situations.

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