

# Application of Minecraft: Education in Mathematics and CMIT Classes, Examples and Practices

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**Abstract:** Games take important part of the daily life of modern students as they are a source for not only leisure but also a useful tool in the hands of the teachers. The authors explore the possibilities for application of game-based learning within the Bulgarian educational context - specifically, different approaches to integrate the popular sandbox game *Minecraft: Education* into the classroom. The study presents several ideas of lesson units for the subjects "Mathematics" and "Computer Modelling and Information Technologies (CMIT)" designed to enhance the teaching and learning process. To assist the development of these lessons, the authors have structured a framework to describe such game-based activities. These ideas are tailored for lower secondary school (aged 11-14) in Bulgaria, offering a different approach to immerse students into the learning process.

## 1 INTRODUCTION

A great part of students' daily life takes place at school, where they are often placed in a situation that is contrary to their wishes and interests. They fill the spare minutes between lessons and/or free periods with what they find most interesting - games, music, films, books.

One of the most popular activities for students are games – computer games, board games, sports. On average, computer game players spend more than 8 hours per week playing games (*Men Spent 5.6 Hours per Day in Leisure*, n.d.). Playing some genres of games uses and develops various cognitive skills such as memory, attention, perception (Granic et al., 2014). A variety of skills are also developed - not only technical but also social. Players gather in themed forums and groups discussing even the smallest details of the game they are interested in. Game-based learning is one of the tools that allows us to use games and their advantages to support the learning process, which is often challenging for students.


One of the characteristics of games that Garris et al. describe is imagination: "Games involve imaginary worlds; activity inside these worlds has no impact on the real world; and when involved in a


game, nothing outside the game is relevant"(Garris et al., 2002, p. 447).

This immersion in the imaginary world enables teachers to tie the learning material to a variety of game worlds and mechanics and to introduce the learning content into familiar situations for students. Examples of the application of games in learning are found at national level. For example, the game "*This war of mine*" is proposed as a learning element by the Ministry of Education in Poland and curricula and materials for teachers have also been created (*This War of Mine*, n.d.). *Minecraft: Education*, an educational version of the game *Minecraft*, popular among students, provides one such possibility.

In the paper, the authors examine the possibilities of implementing game-based learning using *Minecraft: Education*, and present a developed conceptual framework to support the construction of such kinds of lessons, that is yet to be validated and tested. Lesson plans based on the framework, that were developed using *Minecraft: Education*, are demonstrated.

The presented ideas are drawn from the authors' teaching practice in Mathematics and "Computer modelling and information technology (CMIT)" at lower secondary school, which has enabled relevant

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analyses, conclusions, and perspectives.

## 2 RELATED RESEARCH

Game-based learning is not a new idea and has been explored by numerous authors who have found both advantages and disadvantages. Wouters et al., in his meta-analysis reviewed the research of 30 authors, from which they drew the following conclusions:

- The use of games in learning helps to build lasting knowledge. As the authors describe it, "... games lead to well-structured prior knowledge on which learners can build on during their learning career" (Wouters et al., 2013, p. 259). The longevity of knowledge is also confirmed by other authors - Svorotova writes that board games allow for fast, better and complete memorization of information due to the dynamic, varied repetitive, intensive and practical use of information from associative memory. (Svorotova, 2019).
- Another conclusion presented by Wouters et al. is that when games are combined with other learning methods, the effectiveness of learning is increased. Game-based learning on its own is no more effective than traditional lecture, but when combined with other learning methods, games show their effectiveness. This may be due to the fact that when using games alone in learning, students gain intuitive knowledge rather than verbalising and structuring it (Wouters et al., 2013).
- While a common assumption is that games increase students' motivation to learn, Wouters showed in his meta-analysis that they are no more effective in terms of learner motivation than other learning methods (Wouters et al., 2013).

It can be seen that game-based learning cannot replace traditional learning, but the application of games in the classroom can complement and support the building of students' knowledge and skills. The role of the teacher in organising this type of learning should not be forgotten.

The teacher, who should be the mentor and helper of the students/players, is particularly important for the successful implementation of games in learning. As Noemi and Maximo describe, "The work involved in tutoring is the key to guiding the learning process in serious games..."(Noemí & Máximo, 2014, p. 231). The same authors also describe the following

key points for a mentor to follow (Noemí & Máximo, 2014):

- Setting goals to be achieved.
- Defining the concepts that need to be practised and reinforced by serious games and what competencies can be encouraged.
- Setting a framework for the teacher to follow and at the same time check that the objectives are being met - continuous feedback and support for students who are getting discouraged.
- Create a definitive feedback tool for the whole group.
- Reflection on the use of the game (how and when the game triggers moments of reflection and evaluation of the knowledge and understanding gained by the learner)

An important element in defining game-based learning is also the selection of tasks and challenges for students - they should not be too easy, which will bore them, nor too difficult, which will discourage them from continuing. As Dörner et al. say, "The appropriate balance of task difficulty and skill level ensures that the double mission of serious games is accomplished: being both effective and attractive". (Dörner et al., 2016, p. 12).

To implement game-based learning, teachers have many options - educational computer games, board and role-playing games, etc. The authors focused on using *Minecraft: Education* - a specially developed educational version of the popular game *Minecraft*.

### 2.1 Minecraft: Education

Since its release in 2011, *Minecraft* has become a phenomenon in the gaming industry. The game immediately gained popularity among learners. In 2023, the game was the first one to reach 300 million sales ("Minecraft Becomes", 2023). *Minecraft* is a game of the sandbox genre - games in which there is no set goal, and the player is given the freedom to set it themselves. Some of the players' activities are gathering resources, exploring the virtual world, surviving in the wild, but most importantly the ability to be creative through building. The cube system used in *Minecraft* allows for easy construction of unique buildings and structures such as castles, houses, cities, and more. This freedom of action encourages creativity and exploration in players.

Study shows that *Minecraft* can help to develop 21st century skill as Collaboration, Communication, Critical thinking and Creativity (Hewett et al., 2020)

*Minecraft: Education* is a specialised version of the game that is targeted for classroom use. This version has been extended with options for teachers

to present learning content in an engaging way. Such examples are:

- setting up virtual classrooms, such as a chemistry lab with the possibility of conducting experiments
- to recreate sites of historical battles
- to examine animal habitats in detail
- to program and control a personal robot to learn programming concepts

Also, the educational version of *Minecraft* facilitates the teacher's work of creating virtual worlds through some options such as:

- Creating and administering a game server.
- Managing and limiting players' (students') possibilities.
- Additional blocks to limit students.
- Placement of non-game character and chalkboards to support presentation of learning material.
- Additional tools such as camera and portfolio for students to document their progress and creativity.
- A dedicated programming environment where block or scripted programming can be used.
- A collection of pre-made worlds with lesson plans and materials on a variety of topics.

*Minecraft: Education* provides a collection of lessons and teaching material in different subjects, as well as a possibilities for teachers to share their practices and ideas to the community. (*Resources for Minecraft Educators*, n.d.) The community of teachers is diverse and covers different subjects and skills (Bar-El & E. Ringland, 2020).

One possible direction of teaching with *Minecraft: Education* is in the field of computer science as it provides a favorable context for developing a computational thinking (Kutay & Oner, 2022).

## 2.2 Examples of Applications of Minecraft Education

Bulgarian educational system is structured in 3 stages – primary, lower secondary and upper secondary. In the paper the focus of the author is on the lower secondary stage where students are 11-14 years old. In this stage “Mathematics” and “Computer modeling and Information technologies (CMIT)” are compulsory subjects for all students.

The focus of the subject CMIT is to develop student's ICT knowledge and skills like work with word processing, spreadsheets, presentation etc.

The idea of Paul Watkins, a teacher from the UK, to design, plan and calculate the materials needed to build a house could be used for CMIT lessons. This idea uses spreadsheet as a tool and involves several stages (Watkins, n.d.):

- Building design
- Calculation of building costs
- Progress tracking
- Interior design
- Interior costing
- Analysis of overall project

Although initially Paul's lesson is not tailored to the Bulgarian educational system, the implementation of such a learning activity allows to cover the knowledge, skills and competences as expected outcomes set in the curricula for 6th grade, such as the application of different data formats, the introduction of formulas, the application of built-in functions to perform calculations.

## 3 LESSON UNITS

It is noticeable that several game concepts can be traced back to the lessons and ideas presented above, which Andrew Stott and Carman Neustaedter describe as successful when applied to learning (Stott & Neustaedter, 2013):

- Freedom for mistake
- Constant and fast feedback
- Progression
- Plot and roles

Based on these core game concepts, the experiences of other teachers, and the many materials developed, the authors offer several ideas for implementing *Minecraft: Educational* in the CMIT and mathematics classroom. To facilitate these ideas, the authors have developed a framework for describing a game-based activity using *Minecraft: Education*:

### Section 1: Design of Learning Activity

1. Type of learning activity
  - What is the type of lesson - for practice or to introduce new knowledge?
2. Overview of learning objectives and content
  - What are the learning objectives of the lesson?
  - What is the main learning content that will be studied/practised in the lesson?
3. Skill development
  - What domain-specific skill will be developed during the lesson?

- What transversal skills (presentation skills, communication skill etc.) will be developed during the lesson?
  - What type of thinking (critical, algorithmic, logical, computational etc.) the activity provokes?
  - How will students solve the presented problems – individually, collaboratively in groups, or competitively?
  - Does the tasks trigger creativity?
4. Knowledge assessment
- How can the students self-evaluate their knowledge?
  - Do the tasks correspond to a level of a chosen assessment taxonomy?
  - Does the task structure help for a progression of knowledge and skills throughout the chosen taxonomy's levels?

## Section 2: Design of Game World

1. Storyline and rules
  - What is the story around which the learning content will be considered?
  - How is the plot related to the learning content being studied?
  - Is the story related to previous lessons?
  - What are the rules and constraints in the world?
2. Progressivity
  - How can students track their progress as they complete the task (e.g., levels, assignments from non-playable characters, worksheet, to-do list, etc.)?
  - Do tasks get more complicated as students move to the next level?
3. Feedback
  - In what ways can students receive feedback (e.g., responses to assignments after completion, feedback from teachers, etc.)?
4. Freedom for error
  - In what ways can students work through a challenging component?
  - What are the opportunities for students to self-correct if they have made a mistake (e.g., starting over, getting a hint, etc.)?
5. Hidden puzzles and characters
  - Are there hidden puzzles, problems, or characters that the players can meet?
  - What is the purpose of the hidden puzzles and the characters (presenting a clue, getting a game object, a score, a badge, etc.)?

In addition to the shown framework, the lesson structure proposed by the creators of *Minecraft*:

*Education* was followed to describe the learning units, which includes the following four elements:

- Learning objectives
- Guiding ideas
- Student activities
- Performance expectation

The lesson units created by the authors, presented below, are designed for teaching, and/or practicing the topics covered in the lower secondary school curriculum in Bulgaria (age 11-14), and an appropriate virtual world has been created in *Minecraft: Education* with a unique story and roles for students.

## 3.1 Creating Digital Images, A View from Different Perspectives

The educational version of *Minecraft* allows you to create cross-curricular connections and build a holistic picture in learning. The authors present an example of a lesson unit interweaving knowledge of Mathematics and Computer Modelling and Information Technology (CMIT), two subjects from lower secondary school curricula in Bulgaria. The scenario focuses on the topics for 5th grade: *Creating and Processing a Graphical Image* from the CMIT curriculum (MON, 2020) and *Fractions* from the Mathematics curriculum (MON, 2021a).

The main goal of the lesson is to learn about a style of creating graphic images - Pixel art. Students are immersed in a story, and each has their own role - an artist who will be presenting their work in a newly opened gallery. Each student will not only have to create their own painting using the Pixel art technique, will also have to calculate the amount of materials needed to make the painting.

### 3.1.1 Lesson Description

#### Type of Learning Activity

Introducing new knowledge

#### Overview of Learning Objectives

In the activity, learners create a graphic image with Pixel art technique and calculate fraction based on the information from the image.

#### Content From Curriculum:

Create and process a graphic image.  
Fractions - parts of a whole.

#### Skill Development

During the game-based activity, students will gain

knowledge about the structure of the graphic images (Pixel) as well as improve their skill of handling fractions.

The task has creative part as students need to create their own picture in the Pixel art technique.

In the activity students are in the same virtual world but they work independently. At the end they are required to showcase their work - using and enhancing their presentation skills.

#### Assessment

The tasks for the students are not only presented in the game world but also on the worksheets that are prepared for the activity. These worksheets help students to track their progress and self-evaluate their knowledge and skills.

The peer review of the presented work at the end of the activity provides an additional insight of possible areas of improvement.

The tasks in the activity are gradually introduce more complex concepts and problems to solve.

#### Storyline and Rules

The students are artists who have been invited to the opening of a new gallery. Renowned artist Crass has presented his collection of works in the Pixel art style. During the exhibition, Crass invites participants to prepare their work for the next exhibition.

#### Progression

Students' progress is represented through the series of related assignments that they receive from the non-playable characters. Students also have a research log (worksheet) in which they fill in completed tasks.

#### Feedback

Students receive feedback during the lesson from the teacher and from non-playable characters in the virtual world.

#### Freedom for Error

If students make a mistake, they have the opportunity to go back and go through the difficult element again. Students can also complete the problems in any order, allowing them to skip the difficult problems.

#### Hidden Puzzles and Characters

There are no hidden puzzles and characters.

### 3.1.2 Lesson Plan

A lesson plan and student worksheets have been developed to accompany the lesson.

#### Curriculum Learning Objectives

Student can:

- Select colours from the standard and expanded colour palette for primary and background colour.

- Create an image with a variety of tools on a given theme.
- Know how to solve basic fractional number problems.
- Model applied situations and solve everyday problems by applying knowledge of common fractions and operations with them.

#### Guiding Ideas

- Recalls the concepts of pixel, raster image, colour pattern, and colour palette with students.
- Introduces the pixel art technique for creating graphic images.
- Introduces the link between mathematics and IT by calculating the total amount of blocks used for a picture on a given part.
- Creates a world for students in *Minecraft: Education* in which they independently go through the problems presented and create their own image using the Pixel art technique.
- Manages the classroom using Classroom mode for *Minecraft* and guides students who are having difficulties.

#### Student Activities

1. In a discussion recalls:
  - a. The concept of pixel and raster image
  - b. The concept of colour pattern and colour palette
  - c. Finding a fraction of a number.
2. Joins to the specially created world in *Minecraft: Education*. Examines the featured images in the gallery created using a technique called Pixel Art and captures 3 of the pictures. Completes the table in task 2 of the worksheet for the painting Fruit.
3. Finds the size of the painting "Heart!" using the given information.
4. Goes to the creative classrooms and presses the number button corresponding to his class number to move to the assigned workspace.
5. Uses the prepared colour blocks located next to the workspace to create an image using the pixel art technique. Selects the primary and secondary colours of the picture.
6. Completes the picture creation log from the worksheet.
7. Moves to the observation platform and views their classmates' paintings.

#### Performance Expectation

1. Students know the concept of pixels.
2. Students can create images using the Pixel Art technique.

3. Students are able to solve fractional number problems.
4. Students can model applied situations by applying knowledge of common fractions.

### 3.2 Statistics and Fishing

The 6<sup>th</sup> grade (age 12-13) mathematics curriculum in Bulgaria includes topics related to learning classical probability and graphical representation of data (MON, 2021b). In games, students often encounter the idea of random events, which can be used to study probability in mathematics. In *Minecraft: Education*, catching a fish is a random event that can be used as a context for practising the concepts covered in the curriculum.



Figure 1: Game world for the fishing competition.

The created virtual world presents a fishing competition in which students will participate. But being fishermen is not their only role - they are sent out for research purposes. Based on the empirical experiment that the students have to conduct in the game, they have to draw conclusions about the world in which they are placed.

For students who are faster and for those who are explorers and prefer to discover the secrets of virtual worlds, additional hidden tasks are set that aim to renegotiate prior knowledge.

#### 3.2.1 Lesson Description

##### Type of Learning Activity

Lesson for practice.

##### Overview of Learning Objectives

The focus of the activity is to enhance and develop student's understanding about classical probability as

well as how statistical data can be collected and organized in different tables and charts.

##### Content From Curriculum

Finding the probability of a random event.

Organizing and presenting empirical data in tables and charts.

##### Skill Development

During the activity, students should use their pre-acquired knowledge and skills to collect and evaluate the gathered data thus provoking their critical thinking.

Organizational skills are necessary for solving the tasks as the students need to organize, interpret, understand, and present the data in tables and charts from the experiment.

Students work independently in individual virtual worlds.

##### Assessment

The problems gradually test students' knowledge of probabilities and data organization – from recalling basic definitions to critically evaluating gathered data. The scaffolding at the beginning aims to help students to level their knowledge to cope with more complex problems.

##### Plot and Rules

Students are explorers who are invited to participate in a fishing competition. They have the additional task of calculating the probability of catching certain fish and tracking changes in the fish population.

##### Progression

Students track their progress by completing the research log.

##### Feedback

Students receive feedback during the lesson from the teacher and from non-playable characters in the virtual world.

##### Freedom for Error

If students experience difficulties during the game, they have the opportunity to reset and start over a difficult for them part.

They also have possibilities to ask for help from non-playable characters that provide the students with hint, necessary knowledge, or parts of the solutions.

##### Hidden Puzzles and Characters

A series of non-playable characters are placed in the virtual world, divided into two groups:

- Characters that provide an additional bonus for helping in the fishing competition.

- Characters with related hidden tasks for students, the completion of which gives a learning bonus (e.g. a grade, praise, etc.).

### 3.2.2 Lesson Plan

As in the previous example a lesson plan and student worksheets have been developed to accompany the lesson.

#### Curriculum Learning Objectives

Student can:

- Calculate the probability of a random event at the simplest level.
- Find an arithmetic mean and uses it to interpret data.
- Organise and presents empirical data in tables and with orthogonal diagrams.

#### Guiding Ideas

- Recalls the concepts of random event, probability, arithmetic mean.
- Supports and guides students as they move through the various problems.
- Tracks students' progress through their worksheets.
- Manages the classroom using Classroom mode for *Minecraft* and guides students who are having difficulty.

#### Student Activities

1. Joins a specially created world in *Minecraft: Education*.
2. Conducts an empirical experiment and records the data (participates in a fishing competition).
3. Presents the data collected on the worksheet using a diagram.
4. Calculates probabilities based on the data from the experiment.
5. Calculates a probability of an event as a percentage from given data.
6. Compare previous data with data from the current experiment.

#### Performance Expectation

1. Students know the concept of probability and random event.
2. Students can calculate the probability of a random event.
3. Students can construct a graph from given data.
4. Students know the basic properties of probability.

## 4 DISCUSSION, BENEFITS AND DRAWBACKS

Using *Minecraft: Education* brings its benefits - the familiar environment for students to quickly find their way around, provides an interesting context and opportunity to apply the knowledge gained, encourages teamwork and creativity in creating solutions for different situations.

In addition to the benefits, several drawbacks are noticed when the presented ideas of using *Minecraft: Education* were established.

One of the problems is the time to prepare and develop materials - in addition to creating a lesson plan and teaching materials, it is necessary to prepare a virtual world with a story for students to immerse themselves in. Preparing an interesting and engaging world for students takes time and effort that teachers often cannot devote.

Conducting lessons using game-based learning may also requires more instructional time - it is necessary to introduce students to the world and the story, the goals and objectives, and the expectations of them. Time also needs to be spent familiarising students with the game - although *Minecraft* is a popular game, not all students might have played it and know the controls.

Also, one should not forget about the technical side when conducting classes using *Minecraft: Education*. Besides the need for a suitable device for each student, it may need to have a good and strong internet connection if the classes are held in a shared virtual world.

The role of the mentor teacher in game-based learning is also crucial. The use of games immerses pupils in an interesting and engaging imaginary world, which helps to create context, but this same world can distract the students from the objectives, and they may find other activities more interesting. *Minecraft: Education* offers tools to constrain students and set a basic and linear path.

The ideas shown in this article present opportunities for implementing game-based learning with *Minecraft: Education*. It is important to note that the topic suggests being expanded and extended with a proper field study on students' motivation and outcomes when using the presented developments.

## 5 CONCLUSIONS

Games are an additional tool that teachers can use to adapt learning content, motivate students, and

diversify lessons. They do not replace other teaching methods but can effectively complement them. In the presented article the authors have tried to show concrete examples of how a virtual game environment can be used to cover the curriculum content of mathematics and computer modelling and information technology. Like any other tool, the environment used - *Minecraft: Education* has its advantages and disadvantages, but its versatility allows to make attractive lessons from different curricular areas.

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