BETTERGEOEDU: THE USE OF MINECRAFT IN TEACHING THE IMPORTANCE OF RAW MATERIALS IN EVERYDAY LIFE. LEARNING TO MAKE CEMENT FROM MINERALS AND ROCKS FOR PRIMARY SCHOOL STUDENTS

J. Herrera Herbert¹, J.L. Costafreda Mustelier¹, C. Peña Narciso¹, P. Westin², Domingo Alfonso Martin Sánchez¹

¹Universidad Politécnica de Madrid (Technical University of Madrid) (SPAIN)
²Sveriges Geologiska Undersökning (Geological Survey of Sweden) (SWEDEN)

Abstract

The use of games as learning tools has proven to be a valuable way to help pupils learn while having fun. By using BetterGeo, which is a modification created by the Swedish Geological Survey (SGU) on Minecraft (one of the world's most popular games), primary school students can become familiar not only with the importance of raw materials in modern life, but also in how these minerals and rocks become part of everything they use in everyday life and start learning basic concepts about geology, minerals, mining, mineral processing, and circular economy.

Alongside the development of the mod, the BetterGeo Project develops free-to-use teaching materials to help teachers and students in this approach to the raw materials sector. This European project is developed with the support of EIT Raw Materials, one of the eight Knowledge and Innovation Communities (KICs) launched by the EIT (European Institute of Innovation and Technology), and funded by the European Commission, whose mission is to help boost the competitiveness, growth, and attractiveness of the European raw materials sector through radical innovation and guided entrepreneurship. The Universidad Politécnica de Madrid (Technical University of Madrid) is one of the partners involved in this pioneering initiative, and this paper describes the idea behind BetterGeo, together with the innovative development of exercises and educational material designed to facilitate primary school students their first contact with raw materials.

Learning to make cement from minerals and rocks is an involving and interesting experience for students under this schema developed in BetterGeo by going one step further and showing first-hand the direct applications of minerals and rocks in the manufacturing of building and construction materials. In this case, they go deeper into what is cement, the main binding element used in construction today and whose composition can accept hundreds of variants including other materials or raw materials.

Using a simple script with short and simple instructions, students will be able to differentiate the most commonly used mineral components and aggregates, becoming able to make their own mixtures by adjusting quantities and setting times. They will also learn to differentiate when a cement reaches its maximum strength and will even be able to experiment with the addition of components from recycled materials or other raw materials that are not normally used in its manufacture, but which add new and interesting properties to this building material.

Keywords: Gaming, interactive learning, raw materials, cement, circular economy, student, uses.

1 INTRODUCTION

Minecraft is an “open-world” or “sandbox” type construction video game originally created by Swedish programmer Markus ‘Notch’ Persson, inspired by some of his favorite games [1] and later developed by his own company, Mojang Studios. It was publicly released in May 2009, and, after various changes, its full version was released in November 2011 [2]. The classification as a “sandbox” game is because players can shape the world to their liking, destroy and build as if they were playing in a sandbox. This has a great advantage over other video games to be used in education since it does not have a linear history or levels that block access to certain parts of the game. From the beginning, the player can make use of the full potential of the video game [3] and the virtual world in which it unfolds is completely safe for children and adults. In addition, the popularity of the Minecraft game has been so great since its inception that one year after its launch it became not only the best-selling game in all history but also the most played.
In 2014 Microsoft bought Minecraft and realized that numerous schools around the world were using video games to teach. That is why two years later, in 2016, the educational version of the game appeared, called **Minecraft: Education Edition**. This version is designed and thought specifically to be used in educational environments. The new Education Edition led Minecraft to become even more present in the classroom, participating in the training of young people in subjects such as Natural Sciences, Chemistry, Physics, Geology, Biology, History, Geography, Ethical Values, Technology, etc. and even other content such as Language and Poetry, through the game. Similarly, it was also used to lay the groundwork for would-be young programmers, teaching them how to use the Redstone in the game. It was the first time that the role of video games was seen in the educational landscape [3].

One of the most important features of Minecraft is the simplicity of the game. Much of the fame that Minecraft has comes from the fact that its learning curve is very short and that the possibilities are almost endless, so it is possible to find activities that can be carried out at all educational levels and subjects.

A clear example of an activity that any user can perform in the game and that does not require any type of preparation by the teacher, is the study of human evolution during Prehistory. If the students access the game and the objective is to survive, they will have to cut down trees, from which they extract wood. With the wood, they can build wooden tools, which allow them to mine stone. With it, they can make stone tools, with which they can extract minerals from the stone. Among these minerals, the most common is iron, from which iron tools can be created. Through discovery learning and a final reflection led by the teacher, the students will not only have learned to survive in the game but will also have experienced first-hand how the different stages of Prehistory occurred, their main characteristics, and implications for life on the planet [3].

Consequently, Minecraft is a game that allows the teacher to transform the classroom, making Minecraft an additional tool to consolidate the knowledge imparted, and which makes possible an interactive education where students learn while they play [4].

In Europe, through the European Green Deal, the EU is taking action to fight climate change and to encourage all citizens to work towards a greener and more sustainable Europe. As part of the European key challenges for integrating sustainability into education, the European Commission has a major interest in having young learners all across Europe being equipped with the skills and knowledge they need to act on the climate emergency and biodiversity loss [5].

But the European Union is also committed to the development and sustainable use of raw materials. “The European Green Deal” document [6] provides an action plan to boost the efficient use of resources by moving to a clean, circular economy, restore biodiversity and cut pollution. To become more competitive as it becomes greener and more circular, the industry will need a secure supply of clean and affordable energy and raw materials. Ensuring the supply of sustainable raw materials by diversifying supply from both primary and secondary sources, is therefore one of the prerequisites to make this transition happen. This involves instilling in society the knowledge of the resources available in the European territory and the rest of the world, what they are used for and what products of daily life exist thanks to them, as well as instilling also the certainty that their existence is finite and limited, so the exploitation of them must be responsible.

In this scenario, the use of a video game, particularly Minecraft, becomes a valuable tool to help students to learn about raw materials and sustainability while having fun. Based on this idea, BetterGeo is a modification created on Minecraft by a consortium of universities, research centers, and companies: Geological Survey of Sweden, SGU (Sweden), Consiglio Nazionale delle Ricerche – CNR (Italy), Geological Survey of Slovenia – GeoZS (Eslovenia), Montanuniversität Leoben (Austria), Tallinn University of Technology (Estonia), Trinity College Dublin (Ireland), Universidad Politecnica de Madrid - UPM or Technical University of Madrid (Spain), Université de Liège (Belgium), University of Limerick (Ireland), Turvallisuus- ja kemikaalivirasto – Tukes (Finland). This mod aims to help primary school students to get familiarised with the importance of raw materials in modern life and start learning basic concepts on geology, minerals, mining, mineral processing, circular economy, and sustainability (Figure 1). Together with the development of the mod, BetterGeo projects also work in the development of learning materials to help teachers and students in this approach to the Raw Materials sector [7].

The project developing this initiative is named BetterGeoEdu and is actively supported by EIT Raw Materials. EIT Raw Materials is one of the eight Knowledge and Innovation Communities created to boost innovation and entrepreneurship across Europe with the support of the European Institute of Innovation and Technology (EIT). Created in 2015 and participated by more than 120 European partners from leading industries, universities, and research institutions from more than 20 EU countries [8], EIT Raw Materials is the largest consortium in the raw materials sector worldwide. Its partners are active
across the entire raw materials value chain, from sustainable exploration, efficient mining, and mineral processing to substitution, recycling, and circular economy. It has the vision of developing raw materials into a major strength for Europe by finding new, innovative solutions to secure supply and improve the raw materials sector in Europe and the mission of contributing to boosting competitiveness, growth, and attractiveness of the European raw materials sector via radical innovation, new educational approaches and guided entrepreneurship [9].

The Raw Materials Academy is the overarching brand of all the educational activities of the EIT Raw Materials. Activities across the entire ecosystem of learners (Ph.D. students, masters’ students, industrial partners, professionals within the raw materials sector, and wider society) foster new ways of learning and teaching by connecting academia, industry, and research organizations. EIT Raw Materials will educate people that will have an intra- and entrepreneurial mindset and will be able to develop their functions in new working environments, fostering the entrepreneurial and innovation skills, knowledge, and attitudes needed for the entre- and intrapreneurs of tomorrow.

In this paper, the idea behind BetterGeo is described together with the innovative development of exercises and educational material designed to make it easy for primary school students the first contact with raw materials and their applications.

2 METHODOLOGY

Gamification and video games as a learning tool have been a hot topic of research for the past few years, and while Minecraft was originally designed as just a game, it turns out that the flexible, sandbox nature of the game makes it a perfect tool for teachers of any subject. Moreover, published research has shown the educational benefits of using the video game Minecraft in areas such as sciences and educational purposes as a teaching tool to transfer knowledge. Most studies, however, address the issue from an external perspective, rather than a student-centred perspective by evaluation from the researchers’ or teachers’ perspectives. This leads to a gap of data from the participants’ perspective and its usage in education. Those studies discuss how Minecraft is used as a simple teaching tool by filling it with content. Likewise, little research has studied in detail the pedagogical designs of the virtual learning environments, or the design of the content within the game [10].

What is clear is that the chosen content design and playability of the online learning environments influence the formal and informal learning outcome of a student in Minecraft. Gamified designed learning environments in Minecraft benefit informal and formal learning experiences [10]. For this reason, together with the development of the mod, the project has five additional primary goals [11]:

- Create educational material for primary schools based on BetterGeo.
• Translate the mod and the material to the different European languages (English, Swedish, German, French, Slovenian, Italian, Finnish, Spanish, and Estonian).

• Hold test lectures in different countries.

• Hold workshops for primary school teachers in the different countries

• Spread the material through the channels of the EIT RawMaterials consortium and the dedicated website

The educational material will focus on teaching raw materials and their importance in everyday life, from extraction to end-product. The game will function as a complement to practical studies, for example learning to identify different raw materials and their applications after working with them in the game. The material is aimed to be user-friendly, easily accessible, and relevant for the different countries and this is the reason why it has been translated to the different European languages.

One of the exercises developed and which is the object of this communication is intended to allow the students to learn about the cement, its uses, importance, and how to make it with the raw materials existing in nature and in the game.

As in other exercises also developed in the project, this one takes advantage of the potential of Minecraft, but it can also be played in the classroom or at home, in a group with classmates, or as a family activity, although it can also be played individually. And analogously to the case of other games developed in the BetterGeo Project, it can be played with Minecraft, or physically with the resources and boxes of rock and mineral samples that are provided in BetterGeo. Therefore, a wide range of possibilities can be covered with the only limit of the imagination.

The combination of a physical game with the online game itself allows the teacher very different opportunities to contribute to the development in the classroom of different capacities of their students, among which are the following:

1. **Learn about resource management.** Students know what they want to build and for what, while developing strategies and learning to improve their organization.

2. **Delve into computer skills.** Minecraft mods are the most used part. It is an engaging environment where students can dive right into the basics of computer language. The process is somewhat long and complex, but there are very different websites that are completely safe and in which teachers and students can find many resources and possibilities to apply to each game.

3. **Problem-solving.** Minecraft is ideal for teaching "doing small jobs to achieve our goal." If we want to eat, we will have to harvest and plant. If we want to build, we will have to find the materials and make the tools. Endless works that will make students aware and can transfer this knowledge to the real world.

4. **Collaboration.** Teamwork and sociability are two factors that develop with the game, making them collaborate with each other and understand the meaning that together they will have more ideas and can create a better virtual world. In addition, this learning can also be carried out in their daily life, facilitating learning from each other.

5. **Creativity.** The creativity and imagination of the students have no borders and that will make none of their projects the same as another and that they will find different methods and techniques, letting their imagination fly. All this, closely related to the previous point, will allow them to share with their colleagues what they have discovered or learned so that they can also develop it in their projects.

6. **Breakdown of gender barriers and other inequalities.** Minecraft in particular has a large community of people with autism, who have found in the game a way to relate to others and express themselves. This not only happens with this group, but also students with High Abilities and learning problems seem to feel more comfortable in the virtual environment, so using the game in collaborative adventures opens a door for them to interact with their classmates.

The interactive game on the manufacture of cement has been developed by a team of researchers from the Higher Technical School of Mining and Energy Engineering of the Technical University of Madrid and allows students and players to discover the manufacturing process of the most used binder in construction, the cement, and the raw materials necessary for its production, taking into account that there are multiple formulas and highlighting the possibility of using recycled materials, among others.

The game begins with the delivery of the first box, which contains cards with questions about the definition of cement (Figure 2), some historical milestones, and the more general classification of the types of cement that are manufactured today.
Each card contains the question and four possible answers, of which only one is correct. Both in the interactive version for multimedia devices and in the physical version with the cards, the student can answer and fail an unlimited number of times until the correct answer is selected. Once the correct answer has been selected, on the back of the card, in the physical version, or through a new screen, in the interactive version, a short text appears explaining why that answer is the correct one. This fact instantly increases their knowledge of cement and makes it easier for them to remember it.

**Figure 2. Game card. Front and reverse (figure taken from the game development)**

Once the question cards in box number one are finished, they are given box number two, which contains other different cards. In this case, it is not a question of cards with questions, but cards with each of the steps in the manufacture of cement. The student or user of the game must order them from beginning to end. In the interactive version, once they are ordered correctly, they will be able to see a short summary video where the whole process is explained to them. In the card version, a simple brochure will be attached that, like the video, details these steps. All the resources developed are available free for users on the web page of the Bettergeoedu project (Figure 3) [12].

**Figure 3 Resources center, accessible online, for teachers and students [12]**

Q

What is the earliest evidence of the use of cement in history?

a) Fifty years ago, after a hurricane destroyed the wooden houses.

b) In the Middle Ages, when castles started to be built

c) In ancient Greece, using volcanic rocks from the island of Santorini.

d) In prehistoric times, to protect cave doors from wild animals.

A

CORRECT ANSWER

Cement was first used in Ancient Greece using volcanic tuffs (volcanic igneous rocks, light, porous in consistency, formed by the accumulation of ash or other very small volcanic elements) extracted from the island of Santorini (Greece), the first natural cements.
With the completion of the first two boxes, the student or user will be able to define what cement is, from when it is used by human beings, what most important properties it has and how it is manufactured today in the cement industry building materials, etc. This will make students wonder what ingredients or raw materials are necessary for it.

In the second phase of the game, the latter will be shown, using two new boxes. The first contains real samples of the most commonly used raw materials for cement manufacturing and three question cards for each raw material in the box. The three questions for each raw material deal with its geological origin, its appearance (color, shape, etc.), and the property by which it is used in the manufacture of cement.

The cards, as in box number one, have four answers and a short explanatory text on the back. Once box number three is completed, following the same procedure as in box number one, the students or users are knowledgeable about the raw materials that make up the cement and, most importantly, they are able to differentiate them and indicate how each contributes to the mix, which reinforces their learning by not being reduced to memorizing only names.

Finally, box number four is delivered. In it there are new raw materials that today are proposed by researchers, to provide new properties or to reduce the environmental impact of manufacturing, contributing to sustainability in the development and manufacture of new cement.

Each raw material in box four, like box number three, carries three cards with questions, answers, and the official answer. In this case, the questions are about the geological origin, the physical aspect, and most importantly, how they can improve the current cement mixes made with the raw materials from box three.

With the completion of box number four, it will have been possible to update the latest advances in research in cement, students or users not so advantaged, awakening a spirit of continuous improvement and awareness about compliance with sustainability.

3 RESULTS

Although the development of this exercise within Minecraft is its initial stages of implementation and dissemination, the most important achievement of this tool is that the student manages the entire process himself. This goes in line with other exercises developed in this project and that demonstrated to become an excellent complementary educational tool that is easy for teachers to use, having favorable initial reception in the field of complementary school activities or even extracurricular activities.

After having been preliminarily tested with success in activities with students and teachers, an improved version will be launched incorporating the suggestions and conclusions provided by users, monitors and teachers involved. This guarantees, to a certain extent, a good reception by other educational centers apart from those that participate in the tests within the project and for which the development team has continued to develop educational tools such as the one proposed in this communication.

4 CONCLUSIONS

The game consisting of different exercises and activities, proposed as an educational method, allows primary school students to be able to begin to recognize as many varieties of minerals and rocks as they wish. It also has the advantage that it can be accessed from any computer medium and from anywhere and is also free. It is an innovative, fast, comfortable, interactive, and efficient learning system.

The method can be adjusted to different levels of complexity, depending on the age of the student; that is, it can be aimed at students from primary school to university education.

If the degree of penetration of the game is sufficiently important, in view of the preliminary results, its implementation in practical teaching in higher education centers and in undergraduate university teachings is perfectly plausible.

Another possible application is the reinforcement in the acquisition of skills of students who do not pass ordinary exams and where knowledge can be reinforced with the help of this game in order to be able to pass the level tests in geology subjects.
ACKNOWLEDGEMENTS

Special recognition should be given to the EIT Raw Materials and its Raw Materials Academy for funding this project and allowing the development of these innovative initiatives. The authors would also like to thank the different universities and institutions who decided to participate with the confidence of creating something really new.

REFERENCES


