Can we teach children geology using one of the world's most popular video games?

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With an increasing global demand for raw materials, along with an ageing work force in Europe and public distrust for the sector at large, there is a rapidly growing need to work with public awareness and education within the subject of geology. By using innovative tools and models such as gamification, we can develop and nurture interest in raw materials and geology for the future workers and policy makers within the EU. BetterGeoEdu is a project that targets primary schools by providing teacher resources on raw materials, circular economy and sustainability using BetterGeo – a modification of the immensely popular video game Minecraft. The gamification model is used to engage and motivate students by inspiring creativity and learning while having fun.

Avec une demande mondiale croissante de matières premières, une main-d'œuvre vieillissante en Europe et la méfiance du public à l'égard du secteur dans son ensemble, il est de plus en plus nécessaire de travailler avec la sensibilisation et l'éducation du public dans le domaine de la géologie. En utilisant des outils et des modèles innovants tels que la « gamification », nous pouvons développer et nourrir l'intérêt pour les matières premières et la géologie pour les futurs travailleurs et décideurs politiques au sein de l'UE.
BetterGeoEdu est un projet qui cible les écoles primaires en fournissant des ressources pédagogiques sur les matières premières, l'économie circulaire et la durabilité en utilisant BetterGeo - une modification du jeu vidéo extrêmement populaire Minecraft. Le modèle de gamification est utilisé pour engager et motiver les étudiants en inspirant la créativité et l'apprentissage tout en s'amusant.

Con una creciente demanda mundial de materias primas, junto con una fuerza laboral que envejece en Europa y la desconfianza del público en el sector en general, existe una necesidad cada vez mayor de trabajar con la conciencia pública y la educación en Geología. Mediante el uso de herramientas y modelos innovadores como los video juegos podemos desarrollar y fomentar el interés por las materias primas y la geología para los futuros trabajadores y responsables políticos de la UE.
BetterGeoEdu es un proyecto que se dirige a las escuelas primarias al proporcionar recursos para maestros sobre materias primas, economía circular y sostenibilidad utilizando BetterGeo, y una modificación del inmensamente popular videojuego Minecraft. El Video Juego se utiliza para involucrar y motivar a los estudiantes al inspirar la creatividad y el aprendizaje mientras se divierten.

Background

With an increasing global population and a steadily growing middle class, our need for raw materials has never been bigger. On top of that, decarbonisation of our energy system has sparked interest in new technologies requiring large amount of special minerals and metals, critical in the production of for example batteries, electric motors, and green energy. These raw materials have one thing in common: most of them are still in the ground.

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Today, the amount of exploration and mining in the EU is small in comparison to our consumption of raw materials. The reasons for this are numerous, but one of the core issues stems from mining in the EU being considered as an unattractive investment by several large players within the mining industry. One of the reasons behind the unwillingness to invest derives from the lack of social acceptance and trust towards mining operations. As put by the EU commission themselves in the strategic implementation plan of the European innovation partnership on raw materials, there is a prevailing public distrust in the mining industry – a key problem leading to difficulties in establishing operations. The lack of trust appears to be based on the historical mining legacy and lack of public awareness regarding raw materials and their extraction and use in modern society. One thing is clear – if the public directly opposes mines, a socially sustainable sector will be impossible to secure.

Building public awareness, and by extension trust, for an entire sector across a continent requires both short- and long-term commitments focused for different target groups. The youngest citizens in the European Union, who will grow up to be the next generation of industry workers and policy makers, are vital to this strategy, making primary schools particularly important. However, in many EU countries, especially those represented by the authors of this text, geoscience has been found to have a very low presence in national school curricula in primary schools. As such, it is no wonder that people of all ages have an outdated perception of modern mining,

Figure 1: The diverse geology of BetterGeo.

especially in areas far away from active mine sites (SGU, 2017).

Moreover, we face the issue of an ageing workforce which will need to be replaced by a younger generation in the not-so-distant future (Johansson *et al.*, 2018). But if European youths associate jobs in the raw material sector as dangerous, dirty or male-dominated, then who will choose to work there?

Innovative methods of teaching and gamification

As geology and raw materials may not be stand-alone subjects in many of the EU countries' school systems, an extra incentive might help teachers to discuss the issues in other subjects, such as chemistry, physics, history or social science. This may be done by making all the material digital, with an emphasis on innovation and technical skills. Digitalisation of educational methods, for example by introducing more technical tools in teaching, is increasingly popular and even pushed in the EU agenda. The EUs Digital Education Action Plan aims to provide better digital readiness and tools for schools – for example, helping provide fast broadband connections in the Connected Schools Programme. This goes together well with the notion that future workers within the mining industry will need more digital skills due to the shift to new technologies such as remote-controlled operational systems and autonomous drones and vehicles (EY, 2019). Can we entice teachers with innovative digital material, meeting the goals within the school curriculum while keeping the interest of digital natives?

Enter gamification, the application of games in non-game contexts, as defined by Deterding *et al.* (2011). Games are amazing in the way they catch the interest of the gamer, whether it is by completing different scenarios, getting to the top of the scoreboard, or telling a captivating story. Gamification takes these applications, such as feelings of achievement, cooperation, competition, and storytelling, and uses it in new contexts which are not games in themselves. Many people come into contact with gamification elements every day without even noticing it. Popular gamification applications are for example Duolingo, an app on your phone that teaches foreign languages. The app splits up lessons into different steps you can achieve and gives you incentives such as daily streaks to keep you motivated. Or "Zombies Run", a running app which makes you run faster by telling a gruesome story through your headphones of zombies chasing you while you gather supplies to defend yourself. Or why not LinkedIn, which shows how far you have come in filling out your profile by displaying colorful progress bars and pushes you to create more content by showing statistics, almost similar to leaderboards?

Today, people of all ages spend a significant part of their day playing games, whether it is on a mobile phone, TV or computer. Studies suggest that as children grow older screen time increases, with about 6 hours per day for children ages 8-12 and 9 hours per day for ages 13-18, outside of schoolwork (Rideout, 2015). A significant part of this time is spent either playing or watching others play games, similar to how many watch others play football. Why not use the motivation behind games to learn at the same time as having fun? And why not use it within one of the most popular games in the world?

Minecraft – a game about raw materials and geology

Minecraft is one of the most played video games in the world, with over 100 million copies sold worldwide. It revolves around surviving in an open 3D world by collecting raw materials to create tools and buildings. Mining for metals and minerals is a big part of the game and allows the player to advance in technologies, reaching new environments quicker and more efficiently. To find most of the best minerals, a popular strategy is digging as far down as you can in the crust and systematically searching using tunnels. Naturally, different minerals such as diamonds, iron, coal and gold can be found in the same host rock – simply called "stone". It is not uncommon to find diamonds next to a cluster of iron, coal or gold, or all together within a few meters. While the game is undeniably hugely popular, and does teach the player something about different raw materials and where they come from (i.e. from the bedrock), the geology in the game is very simplified and encourages ideas of mining being a low-tech field, built on manual labour, searching for minerals in deep tunnels under ground.

One of the reasons that Minecraft has become so popular is the huge community built around modifications for the game. A

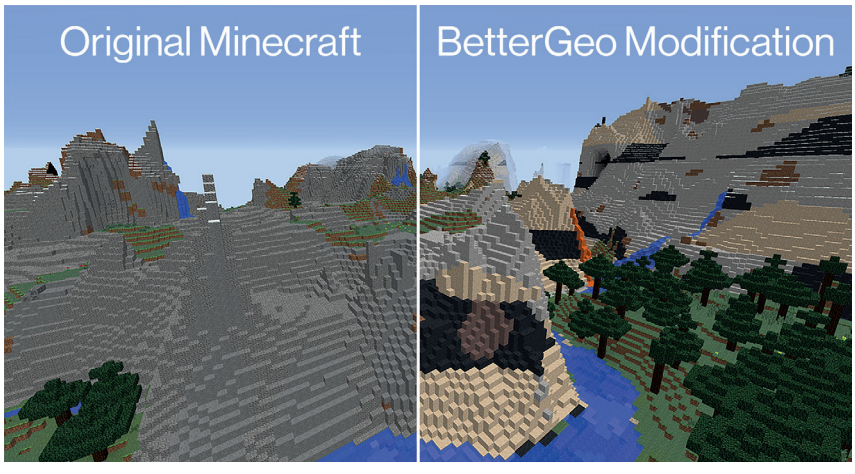

Figure 2: A comparison between original Minecraft and BetterGeo world generation. Note the bedrock diversity in the BetterGeo modification, the first indication for finding the raw material one needs.

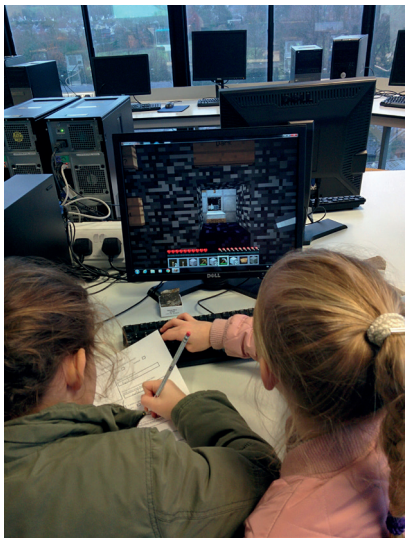

Figure 3: Students playing BetterGeo in Limerick, Ireland.

modification, or "mod" for short, alters the original game in different ways, for example by adding new items, blocks or features. Mods are created by players for players and can be reached through different player-made platforms. Some mods are small, perhaps adding niche items, while others are huge, even to the point of altering the whole game experience.

BetterGeo – better geology in Minecraft

In 2014, a small team at the Geological Survey of Sweden started to create a mod in order to introduce more realistic geology in Minecraft. The project was part of a larger public awareness measure for geology included in the Swedish mineral strategy. The idea was to meet the target audience in their own arena – gaming. BetterGeo was developed by programmers, communicators, and geologists, with constant input from the gaming community via the player-made platforms for mods.

The BetterGeo mod adds multiple new rock types, including corresponding ores along with realistic locations for them in the virtual world (***Figure 1***). What was called "stone" in the original version is now gabbros, limestones, kimberlites, banded iron formations, quartz veins, shales, schists, gneiss... the list goes on (***Figure 2***). The way Minecraft generates the world has been changed, giving the new rocks a realistic stratigraphy with everything from magmatic, metamorphic, and sedimentary rocks, along with intrusions of different kinds. Even the surface has changed, with soil types now modelled after Swedish quaternary deposits of different tills, pebbles, clay, etc., instead of the original soil that was just called "dirt".

Instead of digging deep, underground tunnels as the only method for mineral exploration, finding raw materials is best done with the knowledge or technology suitable for each specific raw material. For example, iron can be found in large deposits of banded iron formation, often near other sedimentary rocks. The magnetism in the iron-rich rocks can be found by using a magnetic compass, which spins when close to a deposit. To find metals needed in electrical equipment in the game, an electrical conductivity meter can be used. The flower Alpine catchfly grows above copper-rich bedrock, a great indicator for finding the copper ores we need in all electrical tools. While still simplified, the new tools for mineral exploration gives depth to the redefined geology and increases the emphasis on raw materials almost as treasure hunting for children.

Within the new rocks, new metals and minerals can be found and processed. In the original version of Minecraft, ores are put into a furnace to be refined. In BetterGeo, this has been expanded with the smeltery which needs to be prepared with different amounts of energy input to work. For example, it takes a lot of energy to refine aluminium, which is reflected in the energy requirements in the smeltery, while other metals might need less. The smeltery also creates by-products in the form of slag. If you have enough slag you can reprocess it for more metals, but in the end there is always going to be some waste products which you cannot use and have to store in some way. The smeltery also releases ash into the environment, which can be harmful for flora and fauna. By finding new raw materials to construct a flue gas cleaner, ash can be collected and the problem can be solved using innovation. Again, the methods are simplified even in the mod, but give the player a notion of the complexity within metal processing as well as environmental consequences – while also giving alternatives using technology.

Using new-found metals such as lithium, copper, titanium, tantalum and silver, the player can create new items and tools that can assist them in surviving. While "normal" everyday items such as phones and computers might not be intuitive or useful in the game, the new monster scanner, jet pack and heart starter are things that can really help the player overcome the dangers of the Minecraft world. These items use similar raw materials as they would in real life, for example the jet pack uses lightweight metals such as titanium and the monster scanner has a lithium battery that needs to be charged using solar power.

Finding new rocks, minerals, metals and alloys introduces the player to another new set of items – in-game educational books. For example, the first time you find a new mineral, a book is given to you at the same time. This book describes the features of the mineral in real life along with where it can be found and other useful information for young aspiring geologists. The books can be collected in bookcases and tracked through a so-called achievement system, where your progress in the game can be seen. This gives comprehensive tools for learning even more

Figure 4: Students identifying rocks and minerals by comparing with sketches made with the BetterGeo mod.

about raw materials and geology beyond the game elements themselves.

Going further – using Minecraft and BetterGeo in primary schools

It is widely known that learning while having fun increases the brain's ability to take in information. As described elegantly by neurologist Judy Willis (2007):

"When students are engaged and motivated and feel minimal stress, information flows freely through the affective filter in the amygdala and they achieve higher levels of cognition, make connections, and experience "aha" moments. Such learning comes not from quiet classrooms and directed lectures, but from classrooms with an atmosphere of exuberant discovery."

With games and gamification, we can engage students in environments where they can use more of their senses than just their ears, allowing them to explore and actively make use of their creativity (***Figure 3***). Learning by having fun increases the involvement and motivation in the student, which in turn increases the ability of the brain to create long-term memories. Many can relate to this phenomenon by looking back at their school years – there are often certain memories from classes that really stick even until adulthood, possibly due to them being particularly interesting, engaging or fun.

BetterGeoEdu was initiated by SGU, EIT RawMaterials and partners all over the EU to provide primary school teachers with material to teach about raw materials, circular economy, and sustainability with Minecraft and BetterGeo. Teaching resources, installation guidelines and step-by-step instructions are provided freely through the website ***www.bettergeoedu.com***, no registration or payment required.

The idea behind BetterGeoEdu is to use the gamification model, specifically related to Minecraft and BetterGeo, to drive the motivation to learn more about school subjects. In addition, and because some students are already familiar with the concept of Minecraft, a flipped classroom approach can rapidly be implemented as an educational strategy by the teacher using BetterGeoEdu. Exercises provided by the project can be used either "online" with computers, letting students actively play the game, or "offline" by using game elements and inspiration without using computers. Two examples are summarised below.

Using computers, one exercise on the BetterGeoEdu platform called "Rocks and minerals" takes the students through a set of rooms in the virtual world. In each room, the students examine a rock or mineral and sketch it on paper while trying out hardness and other features of the samples. When all rooms have been completed, the students put away the computers and get to identify real samples of rocks and minerals by comparing them to the sketches and experiments they made in the game (***Figure 4***). A discussion can be held in the class to introduce the students to the rocks and minerals and what metals we can extract from them in real life.

An "offline" example of an exercise is the "Rock memory". This exercise uses real rocks and minerals that are supposed to be paired with pictures of the same within the BetterGeo mod. While the students try to match the right samples with the pictures, the teacher can discuss and make the connection between the game and real life. This is a short, simple exercise that requires little preparation.

As of November 2020, BetterGeo has been downloaded more than 50,000 times. Train-the-trainer workshops have been held with hundreds of teachers throughout the EU, and more will be held in the continuation of the BetterGeoEdu project. Today, the BetterGeoEdu 2.0 project is coordinated by the Geological Survey of Sweden in collaboration with the Technical University of Madrid, the Geological Survey of Slovenia, Trinity College Dublin, Tallin University of Technology, the University of Liège, the National Research Council in Italy and Montanuniversitaet Leoben. The project is funded by the European Institute of Innovation and Technology (EIT), within the Knowledge and Innovation Community called EIT RawMaterials.

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