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Differentiated Science Instruction in the Metaverse with Gifted Students: Let's Visit Kaz Mountains National Park!

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ABSTRACT

A differentiated science activity was created for gifted students. The focus is on Sustainable Development Goal 15 (SDG-15) for life on land, enhancing engagement, self-regulated learning skills, and scientific creativity in gifted students. The activity spanned eight lesson hours, with tasks encouraging observation, inquiry, and creative thinking. Evaluation included achievement, process, and product forms, along with teacher observations and student feedback. Differentiating the learning environment and process through the utilization of Metaverse and immersive virtual reality technologies is crucial as it affords gifted students the chance to explore novel strategies in differentiated science education. In this particular context, three 3D scenes were created and imported into the Imedu Metaverse platform. Students used laptops to view 3D scenes at three separate occasions. During their visits, they examined living and non-living components of the forest ecosystem, including natural life and environmental conditions. Students experienced immersion with Oculus Quest 2 VR headsets. Following this encounter, they participated in querying procedures. Before and after utilizing applications within the Metaverse, efforts were made to enhance awareness of SDG-15 and foster scientific creativity.

Key words: Gifted students; differentiation; SDG-15; Metaverse; immersive virtual reality.

Özel Yetenekli Öğrencilerle Metaverse'de Farklılaştırılmış Fen Öğretimi: Kaz Dağları Milli Parkı Ziyaret Edelim!

ÖZ

Bu çalışmada, özel yetenekli öğrenciler için farklılaştırılmış bir fen etkinliği tasarlanmıştır. Etkinlik karasal yaşam Sürdürülebilir Kalkınma Amacına (SKA-15) ve özel yetenekli öğrencilerin katılımlarını, öz-düzenleyici öğrenme becerilerini ve bilimsel yaratıcılıklarını geliştirmeye odaklanmaktadır. Etkinlik sekiz özel yetenekli öğrenciye uygulanmıştır. Etkinlik sekiz ders saati boyunca sürmüş ve gözlem, sorgulama ve yaratıcı düşünmeyi teşvik eden görevler verilmiştir. Değerlendirme, kazanım, süreç ve ürün formları ile öğretmen gözlemleri ve öğrenci geri bildirimlerini içermiştir. Öğrenme ortamını ve sürecini Metaverse ve sürükleyici sanal gerçeklik teknolojileri kullanarak farklılaştırmak, özel yetenekli öğrencilerin fen eğitiminde farklılaştırılmış stratejileri keşfetmelerine olanak tanıması bakımından kritik bir öneme sahiptir. Bu kapsamda üç farklı 3D sahne tasarlanmış ve Imedu Metaverse ortamına sahneler aktarılmıştır. Öğrenciler, dizüstü bilgisayarları kullanarak 3D sahneleri üç farklı zamanda ziyaret etmişlerdir. Her bir ziyaretlerinde orman ekosisteminde yer alan canlı ve cansız organizmalara, doğal yaşam, çevre ve atmosfer koşullarını incelemişlerdir. Öğrenciler Oculus Quest 2 VR başlıkları kullanarak sürükleyici bir deneyim yaşamışlar, bu deneyimden sonra sorgulama süreçlerine dâhil olmuşlardır. Metaverse ortamındaki uygulamalardan önce ve sonra SKA-15 farkındalığına ve bilimsel yaratıcılığı geliştirmeye yönelik uygulamalar gerçekleştirilmiştir.

Anahtar kelimeler: Özel yetenekli öğrenciler; farklılaştırma; SKA-15; Metaverse; sürükleyici sanal gerçeklik.

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INTRODUCTION

In today's rapidly evolving educational landscape, addressing the diverse needs of learners has become a critical priority. This is especially evident in the case of gifted learners, who exhibit exceptional skills and necessitate personalized educational opportunities to maximize their capabilities. The field of gifted education has long emphasized the significance of differentiated instruction, which centers on students and adjusts teaching approaches, materials, and educational encounters to suit their unique levels of readiness, interests, and learning characteristics (Subotnik et al., 2011; Tomlinson, 2014).

Differentiated instruction may be executed utilizing a variety of approaches that target differentiation in content, process, product, and learning environment (Roberts & Inman, 2023; Tomlinson, 2001). Adapting the complexity, depth, or pacing of the curriculum based on students' readiness levels and interests characterizes content differentiation (Kaplan, 2009). Process differentiation involves the adjustment of activities, instructional strategies, and learning experiences to align with students' learning preferences and needs (Tomlinson & Imbeau, 2023). Providing students with diverse opportunities to demonstrate their comprehension in ways that match their strengths and interests defines product differentiation (Tomlinson, 2001). Lastly, learning environment differentiation entails the creation of adaptable and responsive learning settings that cater to diverse learners (Tomlinson & Moon, 2013). Through the provision of these methodologies for differentiation, alongside suitable challenges, enrichment tasks, and avenues for advanced learning, differentiated instruction endeavors to cultivate the distinctive capabilities and talents of gifted students (Callahan et al., 2012; Tomlinson et al., 2003).

Nevertheless, the successful execution of efficient differentiation necessitates a profound comprehension of the cognitive, emotional, and social requirements of gifted learners, alongside the availability of specific tools and training opportunities for teachers (Callahan et al., 2015; Tomlinson, 2014). Emerging technologies, like the Metaverse, present promising possibilities for enriching differentiated instruction and establishing individualized, immersive, and cooperative learning experiences (Beck et al., 2023; Hwang et al., 2023; Radianti et al., 2020). The Metaverse is conceptualized as a constellation of enduring, immersive, and compatible virtual realms that individuals can enter via a range of devices including Virtual Reality (VR) headsets, AR glasses, and conventional screens (Beck et al., 2023; Soni & Kaur, 2023). These virtual spaces enable users to interact, collaborate, and engage in shared experiences through digital avatars, simulations, and virtual objects (Mystakidis, 2022). The Metaverse offers multi-sensory, multi-modal learning experiences that transcend physical limitations and geographical boundaries (Beck et al., 2023; Zhang et al., 2022).

Furthermore, fostering engagement, self-regulated learning, and scientific creativity is crucial for nurturing the talents and potential of gifted students (Ayverdi & Öz-Aydın, 2022; Fredricks et al., 2004; Hu et al., 2013; Renzulli, 2012). Engagement involves cognitive, behavioral, emotional, and social components, and is intricately connected to academic success, personal development, and overall health (Fredricks et al., 2004; Wang et al., 2020). Self-regulated learning, characterized by the active monitoring, regulation, and control of one's cognition, motivation, behavior, and environment, is imperative for adept students in managing their distinctive educational requirements and pursuing their areas of interest and enthusiasm (Risemberg & Zimmerman, 1992; Sternberg, 2005; Zimmerman, 2000). Furthermore, fostering scientific creativity, defined as the capacity to produce innovative and valuable concepts, solutions, or products within scientific spheres, can aid proficient students in honing their skills, making contributions to scientific progress, and tackling intricate real-world challenges (Hu et al., 2013; Renzulli, 2012; Sak & Ayas, 2013).

The study firstly aims to explore the intersection of differentiated instruction, the Metaverse, and the enhancement of engagement, self-regulated learning, and scientific creativity. This study has two primary objectives:

- It seeks to develop an activity that addresses the unique needs and skills of gifted students in science education.

- Subsequently, the aim was to assess student participation, self-regulated learning skills, and scientific creativity based on evaluation forms, teacher observations, and student feedback.

In this context, a lesson plan has been formulated utilizing the Integrated Curriculum Model and Kaplan's Grid Model, which are renowned curricular frameworks for gifted students (Vantassel-Baska & Brown, 2007). These two models were employed in developing a comprehensive instructional design, including the current activity. Specifically, the Integrated Curriculum Model was utilized to guide the design in terms of advanced content, process, and product. For advanced content, elements such as a comic book suitable for the students' level, terminology like endemic species and fauna, and SDG-15 content were integrated. The process focused on inquiry-based learning, a key aspect of this model, and tasks aimed at fostering scientific creativity. In terms of product, students were tasked with designing an invention to achieve SDG-15. The Grid Model was applied to further expand the process/product dimensions. Scientific creativity, evidence-based thinking (e.g., presenting evidence from students' observations after Metaverse experiences), research skills such as observation and inquiry, and the creation of an invention (complete with components and operational principles) aimed at achieving SDG-15 were incorporated into this process.

Differentiation was implemented in the design of the activity across various aspects such as content, process, product, and learning environment (Educational Metaverse). The activity was carried out by the first researcher at the Science and Art Center, known as BİLSEM, to instruct gifted students in Türkiye. Students recognized as gifted by specialists have the opportunity to engage in educational programs at BİLSEM.

The Aims and Importance of the Activity

Lack of differentiation for gifted pupils can lead to boredom, disengagement, and underachievement, affecting academic and personal growth (Kanevsky & Keighley, 2003). Differentiated instruction customizes curricula, strategies, and environments to support gifted students, enhancing engagement, motivation, and talent development. Providing an example of differentiation within the realm of science education, this activity strives to enhance students' engagement, scientific creativity, and self-regulated learning skills. Simultaneously, a considerable portion of the occasion took place within the Metaverse setting. This approach also fosters students' cognitive, emotional, behavioral, and social engagement (Makransky & Mayer, 2022), fostering creativity and self-regulated learning skills (Chen et al., 2022). The utilization of the Metaverse for educational purposes with gifted students has not been implemented thus far. Nevertheless, diverse educational interventions have been conducted with gifted students utilizing virtual and augmented reality, the most prevalent Metaverse technologies (Tanik Önal & Önal, 2021; Uçar et al., 2022; Wang et al., 2018). From this perspective, it is posited that this activity will make a valuable contribution to the literature.

This activity pertains to the Sustainable Development Goal "Life on Land" (SDG-15). Gifted students often exhibit a heightened awareness of global challenges and inequalities at a young age, shown through empathy, ethical growth, and interest in societal and ecological issues (Gibson et al., 2009; Hartsell, 2006; Silverman, 1993). Despite understanding climate change well, gifted pupils lack awareness of solutions and often misunderstand climate change concepts (Karahan & Ünal, 2019; Mutlu et al., 2021). They focus on local, not global, environmental issues due to lack of understanding (Nacaroğlu & Bozdağ, 2020; Özarslan, 2022). Educational activities should promote global citizenship and sustainability to equip gifted students with skills for addressing environmental problems and driving change in the future (Slade, 2021). The activity is also expected to raise awareness of SDG-15 and help gifted students generate ideas about environmental issues.

The Learning Objectives

The Ministry of National Education [MoNE] in Türkiye has decided to include the Environmental Education and Climate Change course in secondary schools as an elective course (MoNE, 2022). A workshop focusing on Environmental Education is scheduled to take place at BİLSEM. Nonetheless, the workshop's documentation solely comprises the titles about the content, lacking any details regarding accomplishments and pedagogical approaches. This activity involved the selection of learning objectives aligned with the titles featured in the Environmental Education Workshop content from both the Environmental Education and Climate Change Course Curriculum and Science Curriculum, adapting these chosen learning objectives to suit the distinctive needs of gifted students (Emir, 2021). The learning objectives of the activity are delineated in Appendix 1.

The Outline of the Lesson Plan for the Activity

The lesson plan consists of headings containing general information about the activity, along with seven main sections. The general information includes the activity's name, target audience, duration, learning area/topic, sustainable development goals, big concept/theme, essential question, welcome phrase in the Metaverse, differentiation dimensions, learning objectives, teaching methods, and terms used. In addition to these, the plan includes the following seven sections specific to the activity: 1. Guidelines and Questions Pre-Metaverse, 2. Experience in Metaverse and Immersive VR (IVR), 3. Post-Application Guidelines, 4. Learning Outcomes Assessment, 5. Extension Activities and Research Suggestions, 6. Career Connections, and 7. Interdisciplinary Connections. These sections are for activity implementation.

The activity named *Let's Visit Kaz Mountains National Park* targets gifted secondary school students in the sixth and seventh grade, who are part of the Individual Talent Development Program 2 at BİLSEM. The duration of the activity was scheduled for a total of 8 lesson hours (8x40 min). This activity is related to Science, Biology, and Ecology fields, focusing on the theme of change (VanTassel-Baska & Wood, 2023). Gifted pupils can apply big ideas to various subjects. The theme of change includes four big ideas: i. Change leads to change, ii. Change can be positive or negative, iii. Change happens over time, and iv. Change is planned or spontaneous. The main question is about the impact of human-nature interaction on land life. The activity description for students emphasizes exploring the forest ecosystem in Kaz Mountains National Park. Various learning approaches such as brainstorming, personal analogy, virtual field trip, and discussion are used. Concepts and terminology encompass a wide array of subjects, including Change, Biodiversity, Endemic, Habitat, Fauna, Flora, Ecosystem, Deforestation, Forest Fire, Natural balance, Human-Environment Interaction, and Life on Land (SDG-15).

Ethical Statement

This study was approved by Istanbul University-Cerrahpasa Social and Humanities Research Ethics Committee (approval date: 23/11/2023, approval no: 2023/374). All the children's parents were informed about the content of the study both orally and via written consent formsbefore the study began, and they all approved their children's participation in the study by signing the forms. This study is based on the doctoral dissertation titled "The Effect of Differentiated Science Instruction in the Metaverse on Gifted Students' Engagement, Self-regulated Learning Skills, and Scientific Creativity", conducted by the first author under the supervision of the second author.

ACTIVITY IMPLEMENTATION

Materials

Researchers supplied the materials, which consist of the following items:

- A set of A4 papers
- Various colored crayons
- Each pair of students will need a laptop connected to the internet
- The comic book titled "The Secrets of Future Forests", which can be downloaded from the following link: https://forests.org/wp-content/uploads/SFI-comic-English-WEB-FINAL.pdf
- The Imedu Metaverse Environment
- Oculus Quest 2 Headset

- An Achievement Evaluation Form (Appendix 3)
- Process Evaluation Form (Appendix 4)
- Product Evaluation Form (Appendix 5)

Imedu Educational Metaverse Environment

Researchers create 3 scenes in Blender, then transfer them to IMEDU, an educational Metaverse. IMEDU offers both free and paid subscriptions for users to participate in virtual rooms and engage with others using avatars. Figure 1 shows visuals for training in IMEDU. Users can customize sandboxes in iMedu, accessible via VR headsets or regular desktop/laptop (*Elevate Education & Training with VR and Virtual Worlds*, n.d.)

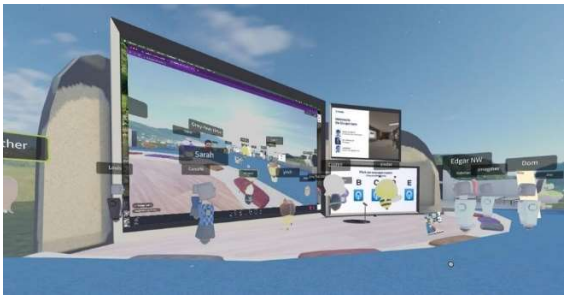


Figure 1. Educational Metaverse Learning Environment of Imedu

Imedu is customized for education. It offers dedicated screens and instructions (See Figure 2 and Figure 3). Users enter scenes through student session information (using link and pass code) The educational Metaverse is secure for students. Synchronous or asynchronous learning is possible. Students can switch between scenes using the navigator menü (See Figure 4).

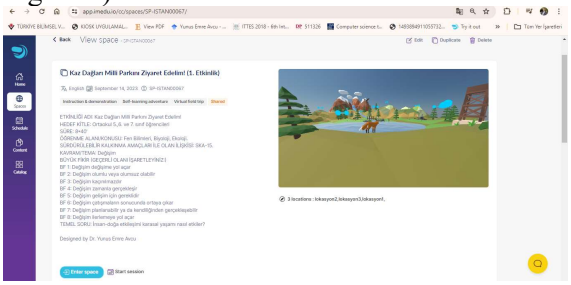


Figure 2. Imedu Teacher Screen

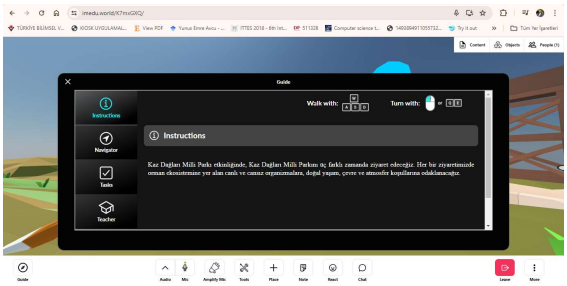


Figure 3. Imedu Student Welcome Screen

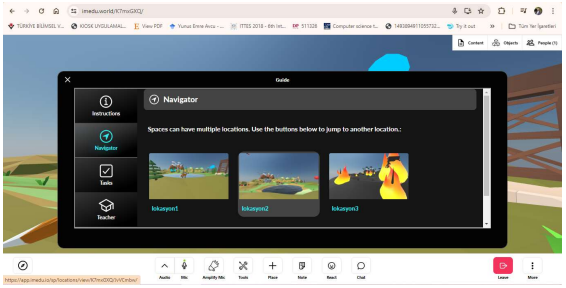


Figure 4. Imedu Navigator Menu

In the first scene, the students enter Kaz Mountains National Park, with endemic trees and plants, welcoming them. The narrator introduces the environment, emphasizing beauty, endemic species, and natural habitats. The narrator points out a Kazdagı Göknarı tree and mentions animals living in the area. Kazdağı Göknarı is an endemic species of fir tree that grows exclusively in the Kazdağı region, contributing to global biodiversity. The lake is essential for all living beings in the region. The park also accommodates visitors camping, playing sports, or bird watching. In the second scene, students in Kaz Mountains National Park will see changes like trees being cut down, tree trunks scattered, and a new gold mine. The forest ecosystem is disturbed, with fewer living creatures and homeless animals. A variegated owl lost its nest and died, while the lake's water levels decreased, causing trouts to die. High levels of CO_2 are present, leading to arid environment, poor soil and air quality, and increased dust. In the third scene, forest fires depicted, linked to climate change due to human neglect or deforestation. Trees and shrubs burn at scene 1, with a smoky sky. Few animals seen, some burned or dead, a rabbit or roe deer tries to flee. Sound of burning trees, bushes, and fire engines heard in the scene. Scenes displayed in Imedu Metaverse environment are shown in Appendix 2.

Procedures

The activity involved eight gifted students, two of whom accessed iMedu via laptop. The students were in grades six to seven. Three students were male and five were female. The students persist in their academic pursuits at BİLSEM for four years.

The content focuses on the forest ecosystem, the interaction between biotic and abiotic components, biodiversity, environmental factors, and deforestation, along with the fifteenth Sustainable Development Goal (SDG-15). Virtual field trips, personal analogy, and brainstorming were employed for process differentiation. In product differentiation, students were asked to design an invention to achieve SDG-15. The Metaverse environment, featuring 3D scenes, was created by researchers for students to explore using computers and the Oculus Quest 2 VR headset in learning environment differentiation.

The achievement evaluation form (Appendix 3) was utilized to assess the content, while the process evaluation form (Appendix 4) evaluated both student experiences and the learning process. Furthermore, the DAP Tools (Appendix 5), as described by Roberts and Inman (2023), were employed to evaluate student products.

The achievement evaluation form consists of fill-in-the-blank, matching, true-false, and open-ended questions, with a minimum score of 0 and a maximum of 100 points. It is designed to assess whether the learning objectives of the activity have been achieved. The process evaluation form is prepared to evaluate the learning process that students experienced during the activity. Students expressed their views by answering open-ended questions, which include prompts reflecting their participation, self-regulated learning skills, and the use of creative thinking abilities through scientific knowledge (scientific creativity).

Product evaluation form (model or invention) is a tool used to assess the quality and creativity of a student's model or invention. It evaluates the content for accuracy and depth, the presentation for clarity, stability, and appropriate use of materials, and the labels for correctness. It also assesses the creativity of the content and presentation, as well as reflection on previous learning, product improvement, and the student's personal learning experience. The performance scale ranges from 0 (no participation) to 6 (professional level).

In the first section of the activity, titled "Guidelines and Questions Pre-Metaverse", scientific creativity is fostered through "What if" questions and prompts aimed at stimulating students' imagination. Similarly, in the second section, "Experience in Metaverse and Immersive VR," students' creativity is triggered by encouraging them to make future-oriented inferences. In the third section, "Post-Application Guidelines," the focus remains on enhancing students' creativity through three specific activities. These tasks target different dimensions of scientific creativity. In Task 1, students critically analyze the importance of SDG-15, enhancing their creative problem-solving abilities and deepening their understanding of environmental issues. In Task 2, they are asked to design an invention to achieve SDG-15, integrating their scientific knowledge with creative thinking to develop practical and innovative solutions. Lastly, in Task 3, students research NGOs that support SDG-15 and share their findings, further promoting environmental awareness while also strengthening both their scientific and social creativity.

The development of students' self-regulated learning skills was intended to be supported through entirely self-directed applications related to the Metaverse and immersive virtual reality. Throughout the activity, students were encouraged to manage their time, organize their learning environment, take notes, and structure their knowledge, implicitly utilizing various self-regulated learning strategies. Additionally, in the process evaluation forms, students were asked to reflect on their learning experiences. All of these practices aim to foster and enhance students' self-regulated learning skills.

The integration of technology, alongside content delivered at an appropriate level of depth and complexity, aims to engage gifted students and meet their cognitive learning needs. Inquiry-based processes tailored to their intellectual abilities, paired group work designed to address their social needs, and the autonomy provided to students are intended to

enhance motivation and increase engagement. The process evaluation form collects data on students' engagement, self-regulated learning, and creative thinking skills. Similarly, the achievement evaluation form assesses the level of student involvement. The product evaluation form, through its various sections, encourages student reflection on their learning process and evaluates the creativity of the final product.

Consequently, the focus is directed towards enhancing the scientific creativity of gifted students, augmenting their engagement, and fostering the development of self-regulated learning skills.

Guidelines and Questions Pre-Metaverse (2x40 min)

Discussing the theme of change involved an exploration of its definition, big ideas, and instances of change across various disciplines. Students were prompted to provide illustrations of the alterations observed in our everyday routines, with a particular focus on changes within life on land.

"What would be the consequences if planet Earth lacked forests?" question was presented to the students. It is anticipated that students will provide articulate, adaptable, innovative, and thorough explanations to this question. Students are advised that they have the option to engage in scientific thinking when brainstorming. Another approach could involve directing students: "*Compose or illustrate your thoughts on a thriving ecosystem."*

The students engaged in a reading activity of the comic book titled *"The Secrets of Future Forests"* followed by a discussion amongst themselves.

Teacher: Great! Let's start with the first question. Why do scientists say that our future depends on forests? What do you think about this?

Student 1: Teacher, forests produce oxygen and absorb carbon dioxide, so they balance our atmosphere. They also host many living creatures.

Teacher: Yes, that's right. Forests play an important role in maintaining the carbon balance in the atmosphere. So, what kind of creatures did you see when you examined the flora and fauna in the comics? Can you give examples?

Student 8: There were many different plants and animals in the comic. For example, I saw large trees, various flowers, birds, insects and some mammals. One of them, the red parrot, caught my attention.

Teacher: Very nice! Forests are home to many different species. How would you explain the relationship of forests with climate change?

Student 3: Forests slow down climate change by absorbing carbon dioxide. Trees store carbon, which reduces the greenhouse gas effect. However, if forests are destroyed, this carbon will be released into the atmosphere and climate change will accelerate.

Teacher: That's right, forests play a critical role in combating climate change. So, how do forests serve life on Earth?

Student 3: Forests produce oxygen, support the water cycle and prevent erosion. They also provide habitat for many plant and animal species. They also provide resources such as wood, medicine and food for humans.

Teacher: Yes, forests support many aspects of our ecosystem and life. So, what can we do to protect life in forests?

Student 5: To protect forests, we must reduce tree cutting and carry out reforestation projects. Additionally, we must be careful and create fire management plans to prevent forest fires.

Teacher: Good thoughts. How can we protect forests and benefit from them at the same time?

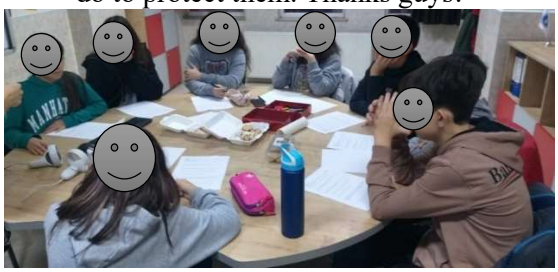
Student 5: We can use sustainable forestry methods. This means planting new trees and using forest resources carefully when cutting down trees. It is also important to recycle and use forest products efficiently.

Teacher: Yes, sustainable forestry is very important. How can forest fires be reduced?

Student 7: We can conduct controlled burns in areas with high fire risk to reduce forest fires. It is also important to clear dead plants within the forest and create fire exit routes. It is also very important for people to be careful and follow fire safety rules.

Teacher: Great ideas. Finally, what does sustainable forestry mean?

Student 6: Sustainable forestry is ensuring that forests remain healthy in the long term by protecting and managing them. This both protects the ecosystem and ensures that future generations benefit from the forests.
Teacher: That's right. You all shared very good thoughts. This discussion about the comic book "Secrets of the Forests of the Future" helped us understand how important forests are and what we need to do to protect them. Thanks guys!



Photograph 1. The Students Participated in a Reading Session of the Comic Book "The Secrets of Future Forests"

Experience in Metaverse and Immersive VR (IVR) (2x40 min)

Scene 1

Pupils are allowed to act in Scene 1. They conducted a thorough exploration lasting approximately 10-15 minutes before exiting the Imedu. It is emphasized that students should carefully observe both living and non-living entities within the forest ecosystem, as well as the natural surroundings, environment, and atmospheric elements during their exploration. Following their engagement in Scene 1, the students responded to the subsequent inquiries.

Photograph 2. Students Investigate Scene 1

- What organisms have you encountered about the fauna and flora of Kaz Mountains National Park? Which living and nonliving entities were observed in Scene 1 and what activities were they engaged in?
- What interactions exist between the living and nonliving components that were observed in Scene 1?
- What is the significance of trees in sustaining natural life, the environment, and the atmospheric conditions?
- What evidence have you gathered indicating that the forests within the forest ecosystem of Kaz Mountains National Park contribute to supporting biodiversity?
- Please present a minimum of three pieces of evidence demonstrating the natural balance and climate stability within the forest ecosystem at Scene 1.

Figure 5. Students Engage with Scene 1 Using Avatars in the Imedu

Sample Student Answer for Question 1: *"I noticed flora elements such as pine trees, oak trees, various plants, and fungi in the Kaz Mountains. As for fauna, I observed deer, foxes, various birds, and insects. Trees perform photosynthesis, birds nest in trees, and insects interact with the soil."*
Sample Student Answer for Question 2: *"Trees provide shelter for birds, insects feed on plants, and the soil supports the life of living organisms. Soil moisture is essential for plant growth. Additionally, trees produce oxygen and help purify the atmosphere."*
Sample Student Answer for Question 5:

- *"The healthy growth of trees indicates that the soil contains sufficient nutrients and water.*
- *The coexistence of various animals (birds, mammals, insects) in a natural cycle suggests the ecosystem is balanced.*
- *Air quality and temperature could indicate the climatic stability of the ecosystem. The green plants and oxygen production by trees also support this balance."*

The students' answers about the role and importance of trees were deliberated. Trees are crucial for maintaining natural balance by contributing to ecosystems and people's needs. They regulate carbon storage and dioxide levels, play a role in the water cycle, maintain temperature, provide habitat for living things, prevent soil erosion, and support biodiversity conservation.

Scene 2

Students have arrived at Scene 2. They were informed that living beings utilize natural resources for survival and can make significant changes in the environment to fulfill human needs. The growing population leads to higher demands, resulting in deforestation and tree utilization. Deforestation is the human-induced process of decreasing or destroying natural forest regions. Students investigate Scene 2 for 10-15 minutes and respond to specific inquiries.

- How can the most recent impact of deforestation be comprehended? What evidence has contributed to this comprehension?
- What are the consequences of carbon dioxide buildup in cases where it is not adequately absorbed in the atmosphere? (The discussion will revolve around greenhouse gases)
- What potential impacts on the environment in the long run can arise from deforestation? What observations have been made in this regard? (The focus is on soil erosion, the water cycle, weather patterns, and biodiversity)
- What are the potential repercussions of deforestation and topsoil erosion resulting from deforestation? What observations were made about this in Scene 2?

Sample Student Answer for Question 1: *"Deforestation's immediate effects are visible through fewer trees and exposed soil, leading to habitat loss and soil erosion*."
Sample Student Answer for Question 2: *"Unabsorbed CO2 accumulates, increasing greenhouse gases, which causes global warming and extreme weather."*
Sample Student Answer for Question 3: *"Long-term effects include soil erosion, disrupted water cycles, and reduced biodiversity, as seen in fewer plants and animals."*

Figure 6. Students Engage with Scene 2 Using Avatars in the Imedu

Scene 3

Students have proceeded to Scene 3. After engaging with the surroundings for 10-15 minutes, they proceed to address the ensuing inquiries:

- What sorts of wildlife observations have you made?
- What are the reasons for a forest fire? Request for evidence supporting your conclusions.
- Envision yourself as a rabbit or roe deer trapped in a wildfire. What emotions would arise? What obstacles would be encountered? In what ways could survival be possible during the blaze?
- What are the potential impacts of wildfires on the ecosystem, biodiversity, and the atmosphere? (Loss of habitat, decrease in biodiversity, release of carbon, air pollution, soil degradation, and effects on water resources should be highlighted).

Sample Student Answer for Question 1: *"I noticed charred trees, damaged vegetation, and displaced animals, showing the fire's destruction."*
Sample Student Answer for Question 2: *"The fire might have started due to lightning or human causes like campfires. Evidence includes burnt trees and lack of fire barriers."*
Sample Student Answer for Question 3: *"As a rabbit trapped in the fire, I'd feel scared and disoriented, trying to escape towards water or an open area."*
Sample Student Answer for Question 4: *"Forest fires cause habitat loss, reduced*

biodiversity, increased carbon emissions, air pollution, soil erosion, and water source disruption."

Figure 7. Students Engage with Scene 3 Using Avatars in the Imedu

IVR Experience (2x40 min)

Following the observation of the immersive content within Imedu through laptops, the students were allowed to individually engage with the aforementioned scenes using an Oculus Quest headset. As one student immersed in the content through an Oculus Quest 2 headset, other students proceeded to complete process evaluation form or conducted further investigations on the subject matter. Visual documentation of students engaging with Immersive Virtual Reality (IVR) can be found in Photo 3.

Photograph 3. Learners Engaged in IVR

Post-Application Guidelines (1x40 min)

Students were tasked with relating events to SDG-15 and performing specific assignments. SDG-15 focuses on protecting terrestrial ecosystems, sustainable forest management, combatting desertification, reversing land degradation, and preventing biodiversity loss.
Task 1: Identifying the importance of SDG-15 is crucial for understanding its significance.
Task 2: Students were required to invent something to achieve the SDG-15 goal by describing its operation and characteristics in detail through drawings and explanations.
Task 3: Research and share information about two NGOs supporting SDG-15, encouraging donations or fundraising efforts for these organizations.

Learning Outcomes Assessment (10 min)

The utilization of the achievement evaluation form in Appendix 3 determines students' attainment level. Students' IVR experiences and learning process evaluations use the process evaluation form in Appendix 4. The design/product evaluation form in Appendix 5 assesses students' designs.

Extension Activities and Research Suggestions (10 min)

Students can research the water cycle, biodiversity importance, and share results via a poster presentation. Students are tasked to compile SDG-15 studies in Türkiye using news, scientific articles, and reports. Literature review on deforestation's impact on microorganisms, climate change, and systems thinking. Students create a public spotlight on rainforest biodiversity, interrelationships, and deforestation effects. Research on bushfires in Australia and how forest creatures adapt to fight them. Study on fire risk assessment in various countries prone to forest fires. All of these have been presented as recommendations for future activities beyond this specific one.

Career Connections (10 min)

Students were informed about various career opportunities such as Environmental Educator, Forester/Forest Scientist, Natural Resource Economist, Nature Photographer, Wildlife Firefighter, Architect, Wood Scientist, and Paper Maker/Materials Engineer.

Interdisciplinary Connections (10 min)

Various disciplines may be connected through the activity. A history lesson could explore the Kaz Mountains National Park's cultural and historical heritage. A geography lesson might focus on its geological structure, features, and climate. An art and design course could express the region's beauty through artistic creations. A literature class might involve reading about Kaz

Mountains. A music lesson could compose music using natural sounds from the region. Technology and design skills might be employed to protect the national park, while a social studies course could address ethical and legal issues related to conservation.

RESULTS AND SUGGESTIONS

In this activity, the gifted students engaged in a visit to the Kaz Mountains National Park within the Imedu Educational Metaverse platform on three distinct occasions. Furthermore, the students' immersion within the Metaverse was enhanced through the utilization of the Oculus Quest 2 VR headset. Accessing the virtual settings within the educational platform was granted to the students in the classroom via a designated password. They proceeded to scrutinize both the animate and inanimate entities present within the forest ecosystem, while also exploring aspects of natural phenomena, environmental factors, and atmospheric elements. Subsequently, they engaged in inquiry sessions about each simulated scenario. Before and after their exposure to the Metaverse and IVR, the students explored comics illustrating changes in life on land, engaged in activities aimed at nurturing their scientific creativity (in pre-metaverse and post-application tasks), and acquired knowledge on SDG-15.

The English Teacher from BİLSEM, who was involved in the activitiy as observer, diligently documented observations. Feedback from students regarding the activity was also verbally communicated. Moreover, the researchers analyzed the assessment documents (including forms assessing achievement, process, and product) that were filled out by the students. The average score of eight students in the activity was 89.25 out of 100, indicating an understanding of the activity content and SDG-15. Verbal feedback and field notes from students confirm this situation. Differentiated teaching affects the academic performance and positive attitudes of gifted students (Eşsizoğlu & Çetin, 2022; Pablico et al., 2017). Teaching with IVR experience in the Metaverse enhances students' understanding of environmental and climate change topics (Makransky & Mayer, 2022; Markowitz et al., 2018).

Gifted students have actively engaged in the implementation process according to the teacher observations. Students have reported enjoying learning, having fun, and losing track of time. Students finished all tasks thoroughly. Students willingly share knowledge with teachers and friends. They engage in inquiry processes, seek creative solutions to problems, and gain a profound understanding of learning materials. Students engage in social interactions in both Metaverse and classroom settings. All of these insights were derived from the teacher's observations. Students with special abilities contribute in various ways to the learning process such as cognitively (Wang et al.,2016), emotionally (Fredricks et al., 2004), behaviorally (Skinner et al., 2009), and socially (Wang et al.,2016).

During the implementation of this activity, students have been able to enhance their self-regulatory learning skills. SRL skills are particularly important for gifted students, as they often exhibit advanced cognitive abilities, intense curiosity, and a need for intellectual autonomy (Kanevsky & Keighley, 2003; Renzulli, 2012). Gifted students who possess strong SRL skills are better equipped to navigate their unique learning needs, pursue their interests and passions, and achieve their full potential (Renzulli, 2012; Sternberg, 2005). During the implementation of the activity, students completed tasks fully, set goals, used learning strategies, and self-monitored (Dignath & Büttner, 2018; Zimmerman & Schunk, 2011). Their answers to questions and feedback from peers and teachers could have helped enhance self-regulatory learning skills through self-assessment and reflection (Dignath & Büttner, 2018; Zimmerman & Schunk, 2011). The guidelines in the Metaverse help students during the same time. The practice of IVR-assisted teaching in the Metaverse promotes autonomy, choice, and self-direction, as well as offers opportunities for supporting self-regulatory learning (Dignath & Büttner, 2018; Renzulli, 2012).

The practice of IVR-assisted teaching in the Metaverse promotes autonomy, choice, and self-direction, as well as offers opportunities for supporting self-regulatory learning (Davies et al., 2013). The techniques used in the activity promoted creativity development. (Davies et al., 2013; Hu et al., 2013). Tasks done before

Metaverse and IVR attracted students' interest and helped them create innovative ideas. In the evaluation form's creativity section, students' products are assessed based on receiving level 4 or 5 scores, indicating their proficiency. Evidence in the literature suggests that students' creativity is enhanced by experiencing IVR in the Metaverse environment (Bourgeois-Bougrine et al., 2022; Wang et al., 2024).

Based on teacher field notes, specially gifted students show high participation in this activity as per researchers. The event occurring in the Kaz Mountains provides a familiar setting for local students, encouraging their involvement. Gifted students wore Oculus Quest 2 VR headsets in the activity to view the Kaz Mountains ecosystem. They saw the ecosystem in its original and degraded state. Additionally, they experienced simulations of forest fires in the Imedu 3D Metaverse platform. Before using the IVR application, students are advised to focus on observing living and non-living elements in the forest ecosystem, including natural life, environment, and atmospheric conditions. Students had difficulty understanding the guidelines because of their strong interest in IVR technology and desire to explore the 3D environment. Hence, students need to comprehend the instructions before IVR technology introduction. Students engaged in IVR while being observed by their peers who then filled out the process assessment form. Providing VR headsets to students enhances activity efficiency. The activity occurs in the Metaverse, incorporating laptops and VR headsets. It offers gifted students a platform to explore innovative methods in science education.

It is acknowledged that additional time is required for the implementation of certain sections in the activity as “extension activities and research suggestions”, “career connections”, and “interdisciplinary connections”. Therefore, these sections lack sufficient detail at this point. Students' increased mental needs must be considered during activities with gifted students (Tomlinson, 2023); interdisciplinary connections should be made (Kaplan, 2009), and students should learn about career opportunities (Brown, 2023). Thus, more time should be allocated to relevant parts of the activity.

The results show the educational Metaverse and IVR can benefit gifted students. They cater to their learning needs and boost their abilities. It serves as a resource for specialists creating instructional designs for gifted students and their teachers. Similar practices can be applied in different disciplinary areas beyond science, including activities for gifted students of various ages. This activity can vary based on age groups and can be differentiated by content, process, and product. The 3D scenes for the activity were created by researchers and enhanced in the Imedu educational Metaverse. Activity can occur in various Metaverse environments including VRChat, AltSpaceVR, Framevr and Spatial, in addition to Imedu. Researchers can share a link to an activity with teachers who can then use it with their students. This study involved students in a classroom setting; distance education can be considered as an alternative implementation.

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Appendix 1

Activity Learning Objectives

1. Questions the significance of biodiversity for natural life (This learning objective has been adapted from the Science Curriculum (MoNE, 2018))

• Emphasis is placed on the vegetation, fauna, rare and indigenous species of Kaz Mountains, and ample water resources.

2. He acknowledges that he is a component of the ecosystem he inhabits, based on his observations (This learning objective has been adapted from the Environmental Education and Climate Change Curriculum (MoNE, 2022)).

• Students are prompted to provide instances of the interplay between humans and nature based on their observations. • They have the opportunity to explore Kaz Mountains National Park and witness the interplay between nature and humans. Engaging in recreational activities in nature (such as camping, hiking, cycling, mountaineering, bird watching, etc.) are avenues for interacting with nature and appreciating the marvels of nature. • Observation towers, hiking trails, and educational signs in Kaz Mountains National Park exemplify individuals' endeavors to safeguard and acknowledge nature. Efforts such as nature preservation initiatives, species conservation, habitat rehabilitation, etc. are also components of the human-nature interplay.

3. Examines the perpetual interconnections between biotic and abiotic elements in the ecosystem (This learning objective has been adapted from the Environmental Education and Climate Change Curriculum (MoNE, 2022)).

• Kaz Mountains National Park is explored, highlighting interactions between living organisms and between living and non-living entities. Discussions revolve around the connection of trees in Kaz Mountains National Park with natural life, the environment, and the atmosphere.

4. Categorizes human actions leading to forest depletion based on the outcomes of his investigation (This learning objective has been adapted from the Science Curriculum (MoNE, 2018))

• Activities such as land conversion for agriculture, mining operations, residential construction, and utilization of trees for paper production are underscored.

5. Assesses the immediate and prolonged repercussions of deforestation, which could trigger adverse alterations in nature, concerning natural life, the environment, and the atmosphere (This learning objective has been adapted from the Environmental Education and Climate Change Curriculum (MoNE, 2022) and it has been elevated from the analysis level to the evaluation level according to Bloom's taxonomy)

• The focus is on the interdependence among all organisms within the forest ecosystem, their interactions, and the indications of ensuing changes

• Attention is drawn to the adverse changes stemming from tree felling, deforestation due to mining endeavors, and forest fires on natural life, the environment, and the atmosphere.

6. Develops an understanding of terrestrial life (SDG-15), a constituent of the sustainable development objectives (This learning objective has been written by reviewing the objectives of the Science Curriculum (MoNE, 2018) and the Environmental Education and Climate Change Curriculum (MoNE, 2022)).

7. Devises an innovation that can facilitate the realization of the objective pertaining to terrestrial life, one of the sustainable development goals (This learning objective has been adapted from the Environmental Education and Climate Change Curriculum (MoNE, 2022)).

Appendix 2

Scenes (Scene1, Scene2, Scene 3) Displayed in Imedu

Appendix 3

Achievement Evaluation Form

A. BLANK-FILLING QUESTIONS

Description: Complete the sentences by selecting the appropriate terms to fill in the blanks (soil-conservation-cause- habitat -role- biodiversity- balance- endemic -human)

The Kaz Mountains are known for hosting a significant number of _____ species. These unique organisms are exclusive to the Kaz Mountains and are not present elsewhere, underscoring the significance of the region's _____. The _____ of trees in maintaining natural equilibrium is vital, given their ecological functions such as oxygen generation and prevention of _____ erosion. Forest fires can have a detrimental impact on ecosystems, leading to biodiversity loss and diminished soil fertility, while also disturbing the _____ within ecosystems. Deforestation stems from various factors including _____ activities and unauthorized logging, which can contribute to the hastening of deforestation processes. The intricate forest ecosystem supports the coexistence of diverse plant and animal species, with the _____ in such ecosystems guaranteeing the sustainable utilization of natural resources and the _____ of species.

B. MATCHING QUESTIONS

Compose sentences denoted by the specified letters and sentences indicated by numerical symbols using arrows or the format A-1 in the lower section of the table.

A	Areas of use of trees	1	Soil erosion, climate change, habitat loss
B	Endemic creatures in Kaz M.	2	The utilization of trees can have adverse effects on habitats and ecosystems
C	Forest fire	3	Promoting species coexistence in ecosystems and sustainable resource use
D	Effects of deforestation	4	Refers to exclusive species dwelling solely in a particular region
E	Natural balance	5	Activities like furniture production, paper manufacturing, and energy provision

C. TRUE-FALSE QUESTIONS

Statement 1: Biodiversity in the Kaz Mountains thrives due to the presence of a single species. True/False
Statement 2: Deforestation can lead to an increase in biodiversity. True /False
Statement 3: Human activities stand out as one of the primary triggers of deforestation. True /False
Statement 4: Trees solely contribute to oxygen production and have no additional ecological function. True /False
Statement 5: Terrestrial life plays a minor role in ecosystems compared to aquatic life forms. True/ False

D. OPEN-ENDED QUESTIONS

Answers to the following questions:
What measures can be implemented to safeguard biodiversity in the Kaz Mountains? What are the potential impacts of deforestation on the atmosphere? How can forests be utilized in a sustainable manner? What strategies can be adopted to prevent forest fires?

Appendix 4

Process Evaluation Form

Student's Name and Last Name:

Activity Name: Let's Visit Kaz Mountains National Park!

Instruction: This self-assessment form serves as a means to evaluate the educational process encountered during the aforementioned activity. Please express your perspectives by responding to the subsequent inquiries.

1. Reflecting on my emotional state during the activity, what were the highlights that brought me joy and the instances that left me disinterested?

2. What were the particular aspects of the activity that posed challenges for me? How did I strive to overcome these obstacles and what approach did I adopt in such circumstances? What were the outcomes of these efforts?

3. How did I engage in interactions with my peers and educators during the activity? What methodologies did I employ both independently and within group settings?

4. To what extent did the knowledge acquired at the activity align with my pre-existing understanding?

5. In what contexts and manner can the knowledge gained from the activity be applied in the future?

6. How do I assess my performance in terms of idea generation and design processes during the activity? Did I produce a multitude of ideas? Were these ideas diversified across various categories? Did my ideation significantly differ from that of my peers? To what extent were my ideas elaborated upon?

7. Reflecting on my emotional responses during the activity, what adjustments would I make if I were to partake in a similar activity in the future?

8. Which segments of the activity did I find particularly significant yet challenging to comprehend? Did I document these aspects for future reference?

9. Was I efficient in managing my time during the activity -related tasks? Did I adhere to the designated learning areas and schedules promptly?

10. What preparatory measures did I undertake before engaging in the learning activities? How did I occupy myself while awaiting the commencement of the instructional sessions?

12. How did I approach the process of learning and understanding the subject matter during and post the activity? (Strategies: revision, organization, etc.)

13. Did I engage in critical inquiry regarding the knowledge acquired at the activity? Could you provide one or more instances to elaborate on this?

14. Did I familiarize myself with the activity guidelines beforehand to comprehend the activity structure and my assigned responsibilities?

Appendix 5

Product Evaluation Form

CONTENT								
	Is the content correct?	0	1	2	3	4	5	6
	Has the content been throyght about in a way that goes beyond a surface understanding?	0	1	2	3	4	5	6
	Is the content put together in such a way people understand it?	0	1	2	3	4	5	6
PRESENTATION								
Representatiton	Doest the model clearly look like what it represents?	0	1	2	3	4	5	6
Construction	Does the contruction maket he model stable? Are the materials appropriate fort he construction?	0	1	2	3	4	5	6
Labels	Are the labels clear? Are the labels mostly free from usage, punctuation, capitalization, and spelling errors? If sources are used, are they cited correctly?	0	1	2	3	4	5	6
Creativity								
	Is the content seen in a new way?	0	1	2	3	4	5	6
	Is the presentation done in a new way?	0	1	2	3	4	5	6
Reflection								
Content	What connection can you make between what you have learned by completing this Project and previous learning?	0	1	2	3	4	5	6
Product	In what way could yu improve your product when completing this product with a different assignment?	0	1	2	3	4	5	6
Learning	How did you amount of sffort affect your learning about the content and creating the product?	0	1	2	3	4	5	6
Comments:								

Meaning of Performance Scale:
6 - PROFESSIONAL LEVEL: The level expected from a professional in the content area
5 - ADVANCED LEVEL: level that exceeds the expectations of the standard
4 - PROFICIENT LEVEL: the level expected for meeting the standard
3 - PROGRESSING LEVEL: the level demonstrates movement toward the standard
2 - NOVICE LEVEL: level demonstrates initial awareness and knowledge of the standard
1 - NONPERORMING LEVEL: level indicates that no effort to meet the standard
0 - NON PARTICIPANT LEVEL: level indicates nothing turned in