



Co-funded by
the European Union

2024

M-STEM

E-BOOK



METaverse-BASED STEM EDUCATION FOR A SUSTAINABLE AND RESILIENT FUTURE

2023-1-FR01-KA220-SCH-000151516

This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Authors: Lycée polyvalent Clément Ader, Malmö Stad, Digitaliseringsenheten, Eurasia R&D Limited, VAEV R&D GmbH, Inspectoratul Scolar Judetean Teleorman, Agrupamento De Escolas De Barcelos, Colegio Séneca S.C.A

This publication was carried out with the financial support of the European Commission under Erasmus + Project “Metaverse-Based STEM Education for a Sustainable and Resilient Future”, 2023-1-FR01-KA220-SCH-000151516

© March 2024 – Lycée polyvalent Clément Ader, Malmö Stad, Digitaliseringsenheten, Eurasia R&D Limited, VAEV R&D GmbH, Inspectoratul Scolar Judetean Teleorman, Agrupamento De Escolas De Barcelos, Colegio Séneca S.C.A

Issued and published by Eurasia R&D Limited (Türkiye)

Attribution, share in the same condition



You are free to:

Share — copy and redistribute the material in any medium or format

Adapt — remix, transform, and build upon the material

The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

NonCommercial — You may not use the material for commercial purposes.

ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original.

No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

Content



About the Project

Work Packages

Partners

Chapter 1: Introduction to the M-STEM Pedagogical Strategy

Introduction

Why MSTEM USE VR?

Theoretical Framework

Interactive Applications of a MSTEM Course

Conclusions

Chapter 2: Integrating STEM with Digital Technology

Understanding the Digital Landscape in STEM Education

Aligning STEM Objectives with Digital Tools

Digital Tools

Practical Implementation Strategies

Collaborative Learning in a Digital Space

Addressing Technology Barriers

Conclusion

Chapter 3: Creating Immersive and Interactive Learning Experiences

Introduction

What is Immersive Learning?

How can you design an interactive learning experience with VR?

Designing Immersive Learning Experiences

Types of Immersion

What are the elements of Immersive Learning Experiences of MSTEM course?

Content

VR STEM Lab as an Interactive Learning Environment
STEM Lab Environment for Sensory Immersion and Spatial Immersion
Conclusions

Chapter 4: Pedagogical Approaches for the M-STEM Project

Introduction
Why is it important to focus on pedagogical approaches?
Pedagogical approaches in short
Experiential Learning
Immersive Learning
Collaborative Learning
Game-based Learning
Personalized Learning
Blockchain Technology
Project Based Learning
Global Collaboration
Digital Literacy and Ethics
Flipped Learning
Conclusions

Chapter 5: The Importance of STEM Education in the Digital Age

Introduction
Education Requirements in the 21st century
The new skills in an era of change
The importance of STEM skills in ensuring a sustainable future
Challenges of STEM education in the digital era
Conclusions

Content

Chapter 6: Introduction to the concept of metaverse and its potential for learning

Introduction

What is Metaverse?

How is the Metaverse perceived?

Common Misconceptions

What added value for learning?

Chapter 7: Discussion on the Benefits and Challenges of using Metaverse technology in STEM Education

Introduction

Introduction to STEM Methodology

Brief History of the STEM

References and relevant authors in the development of the STEM methodology

Benefits of implementing STEM methodology in the classroom

Contribution to the Sustainable Development

Contribution to Inclusion and Equity

Contribution to Active Citizenship

The Need for STEM

Difficulties and challenges facing the implementation of STEM methodology



“The M-STEM project aims to integrate STEAM concepts into the Metaverse by developing an inclusive, innovative, and multi-dimensional approach”

About the Project

Low attractiveness of STEM subjects in schools, a lack of interest in STEM careers, and a mismatch between STEM education and the needs of the digital labour market in the EU continue to pose a challenge that hinders the region's sustainable growth. It is important to increase students' motivation towards studying STEM subjects and to raise their achievement in these areas, as it is crucial for the EU's sustainable and digital growth.

However, current STEM pedagogy, curriculum, teachers, and tools are not adequate to prepare future generations for the demands of the 21st century digital STEM field. Incorporating STEM into new and innovative technology dimensions, particularly in a digital environment, is of crucial importance for both current and future generations.



Work Packages

01 Pedagogical Strategy

The M-STEM Pedagogical Strategy focuses on developing innovative teaching methodologies and approaches specifically designed for the hyper-digital era. The strategy aims to integrate STEM subjects with digital technology and leverage the Metaverse to create immersive and interactive learning experiences.

02 Curriculum and Training Contents

In this work package, we will develop a curriculum that includes learning objectives, outcomes, and STEM skills training content in the Metaverse. The curriculum and training content are complementary aspects of the pedagogical strategy.

03 Creation of VR Simulation

With the creation of a virtual reality simulation platform (VR App) that mimics real-world STEM education scenarios, the project will provide students and teachers with an immersive learning experience that allows them to explore and experiment with STEM concepts in a virtual environment.

Partners



Lycée polyvalent Clément Ader

Coordinator, France



Malmö Stad, Digitaliseringsenheten

Sweden



Eurasia R&D Limited

Türkiye

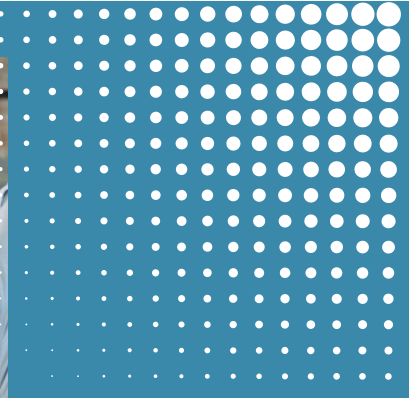


VAEV R&D GmbH

Austria



Partners



Inspectoratul Școlar Județean Teleorman

Romania



Agrupamento De Escolas De Barcelos

Portugal



Colegio Séneca S.C.A

Spain



Chapter 1

Introduction to the M-STEM Pedagogical Strategy

By EURASIA

Introduction



MSTEM Pedagogical Strategy is a learner-centered approach to immersive learning, facilitated by teachers and powered by technology. Immersive learning goes beyond traditional lectures and textbooks. Students actively explore and build knowledge through simulated environments and real-world interactions. Learners experience familiar and unfamiliar scenarios in a safe virtual space. This overcomes limitations like distance, danger, or cost, making impossible experiences possible. Teachers design the immersive environment alongside students, setting goals and assessing progress within the virtual world. They act as guides, not dictators, fostering learner autonomy. Students choose their pace, content, and learning strategies, while teachers provide guidance and ensure alignment with learning objectives. This promotes self-directed learning and ownership. Different types of immersion cater to diverse learning styles and preferences.

Enjoyment is key, as it fuels engagement and deeper understanding. Collaboration and dialogue among learners remain crucial for knowledge construction and refinement, even within immersive environments. Technology like virtual reality and simulations bridge the gap between teacher designed structures and student knowledge construction, providing tools to maximize cognitive potential. Immersive learning prioritizes experiences that are fun and engaging. When students enjoy the process, they learn more effectively and develop valuable skills. Immersive learning is not just about fancy technology; it's about creating a learner-centred environment where students actively engage, explore, and construct knowledge.

Wagner, C., & Liu, L. emphasizes that immersive learning breaks away from traditional models and places emphasis on active engagement. Learners are not just passive recipients of information, but actively explore and construct knowledge through interactive experiences. While drawing the framework of immersive learning, the experts emphasize the following features:

- Learners are placed in simulated environments that replicate real-life situations, making it possible to experience the familiar and unfamiliar in a safe and controlled setting. This allows for learning that wouldn't be possible otherwise due to limitations like distance, danger, or cost.

Introduction - I

- Teacher acts as facilitator. While technology plays a crucial role, teachers remain essential guides. They design learning activities, set goals, and assess progress within the immersive environment. They act as co-creators, shaping the virtual world alongside learners.
- While teachers provide guidance, learners have control over their learning pace, content selection, and preferred strategies. This fosters self-directed learning and ownership of the process.
- There are different types of immersion: sensory, imaginative, and challenge based. Each type aims to maximize learner enjoyment and engagement, leading to deeper understanding and skill development.

Even in immersive environments, the importance of social learning should not be underestimated. Collaboration and dialogue among learners are crucial for knowledge construction and refinement. Effective integration of technology and course structures is essential for successful immersive learning experiences. It should be noted that in this pedagogy enjoyment is considered a key indicator of learning effectiveness.

In sum, immersive learning offers an intriguing vision that goes beyond traditional models. While emphasizing the potential of technology to create engaging and effective learning experiences, the irreplaceable role of teachers in guiding and facilitating the process should also be recognized.



Why MSTEM use VR? _____



Although there is a lack of research in this area, users report that immersive technologies significantly enhance learning because these technologies can simplify and simulate complex concepts.

In this project, we aim to exploit the possibilities of virtual reality for teaching STEM subjects. The immersive, interactive, and accessible tasks prepared for students provide them with the opportunity to access real experiments, 3D objects and educational animations prepared in a virtual lab, giving them opportunities to practice academic STEM skills in a realistic way and creating safe spaces to encourage their full and successful participation in STEM lessons.





Why MSTEM use VR? - I

Researchers Katie Coleman and Brian Derry from the University of Michigan recently conducted a comprehensive survey aimed at measuring students' reactions to training using VR. The results of this survey showed that more than 75% of respondents indicated that the event had an overwhelmingly positive impact on the participating students. A significant majority of the students emphasized their increased self-confidence as a direct result of the event and stated that the VR platform they used served an effective function for practicing. Many students expressed excitement, describing the activity as interesting and realistic. They praised the clarity of the instructions and emphasized the value of the overall learning experience. The potential of immersive virtual environments in enhancing learning experiences has been emphasized by many educators. De Back et al. acknowledge the limited adoption of these environments in education but suggest that one reason for this may be the lack of effective design recommendations. Designing immersive learning environments improves cognitive skills and encourages collaborative learning. Utilizing the unique features of the VR platform reduces physical limitations, allowing for the creation of an efficient and cost-effective immersive learning environment for both students and educators.

Theoretical Framework

Immersive technologies combine real and virtual worlds, creating experiences that feel artificial but real to users. The use of immersive technologies in education helps students visualize abstract concepts. Immersive technologies also help students develop specialized skills that are more difficult to achieve through traditional education. Researchers have shown that immersive technologies increase engagement and strengthen participation. The use of innovative educational methods based on immersive technologies is very important, especially for today's internet generation students (D. Fonseca et al., 2014).

In today's education, visualization, interaction, personalization, and gamification have become very important elements. The prevailing view is that learning is more effective through practice, through feedback that tells you what was done right and what was wrong, and how to get better. In STEM education, the necessity of thinking and practicing like a scientist in the field is undeniable. Therefore, VR has become a very effective tool. Practical training can be provided by creating artificial environments in different fields using VR. For example, anatomy can be explained using medical simulations, while language skills can be improved by establishing interactions with the help of social environments. This practical approach is an ideal solution for STEM education (Salvetti, F., & Bertagni, B., 2017).

Fowler (2015) proposed a pedagogical approach for the use of Virtual Learning Environments in education. Fowler first introduces the stages of learning and explains how they can be represented in learning experiences in virtual learning environments. In the first stage of conceptualization, the learner becomes familiar with the topic and gains a basic understanding. In virtual environments, this is the case, for example, where a particular concept is presented visually, and the learner is free to explore and interact with it. The second stage of the structure involves active interaction with the topic, which leads to an advanced understanding. In virtual environments this is associated with higher realism with more possibilities of hands-on interaction with the subject. The third and final stage, dialog, is about discussions with others to confirm and further consolidate understanding. In virtual environments this can be facilitated, for example, through the representation of oneself and others as avatars (Tycho T. De Back et al, 2021).

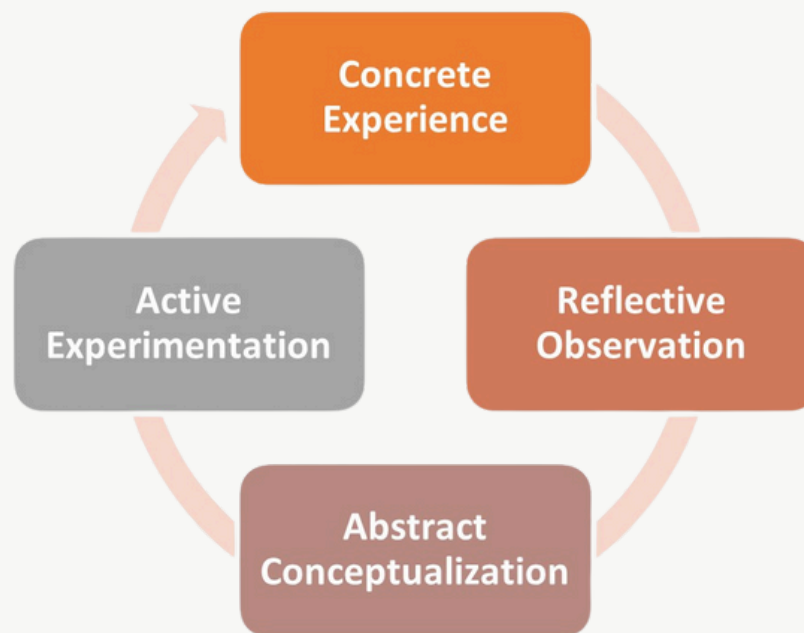
Theoretical Framework - I

Fowler lays out a pedagogical "design for learning" approach in which the intended learning outcomes are first identified in order to reach the learning requirements for each of the three learning stages. These learning needs are similar to Dalgarno and Lee's (2010) learning benefits. It is then assessed whether the learning requirements for each phase are adequately supported by the potential learning benefits of virtual learning environments and their underlying characteristics (Tycho T. De Back et al, 2021).

MSTEM pedagogy involves an approach where learning is student-centred and it is based on several learning theories:

1- Experiential learning - students should work with partners

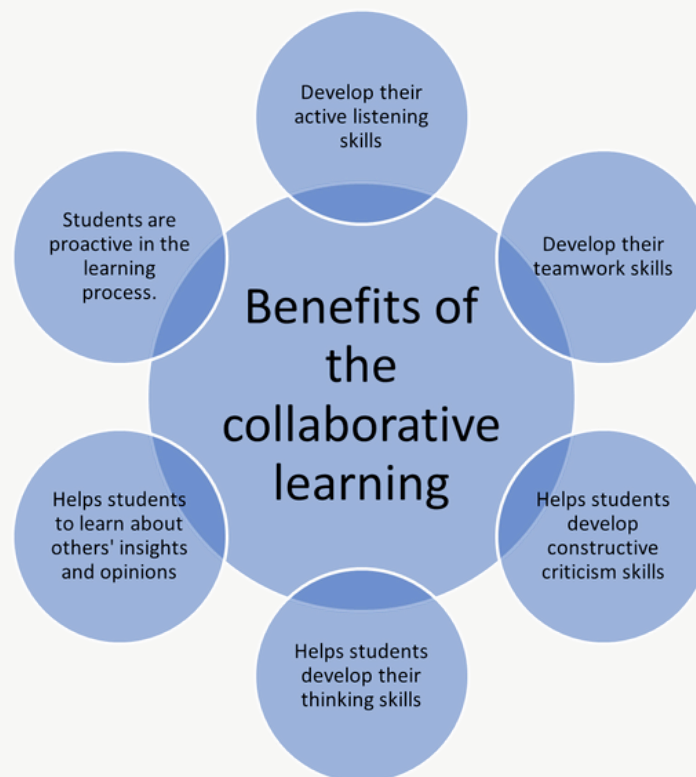
It is best practice to create a variety of learning experiences for students with different learning styles. Exposing students to a variety of learning experiences will also help them to become more adaptive and well-rounded learners.



Theoretical Framework - II

2- Collaborative learning

In Collaborative learning the activities should include encouraging students to work in groups. In collaborative learning approach, students work together on activities or learning tasks in a group small enough to ensure everyone's participation. Students in the group work together on a common task. In some cases, students may work on separate tasks that contribute to a common outcome. Collaborative learning activities may vary as peer learning, roleplaying, and debate. Students may form project groups, discussion groups, writing groups.

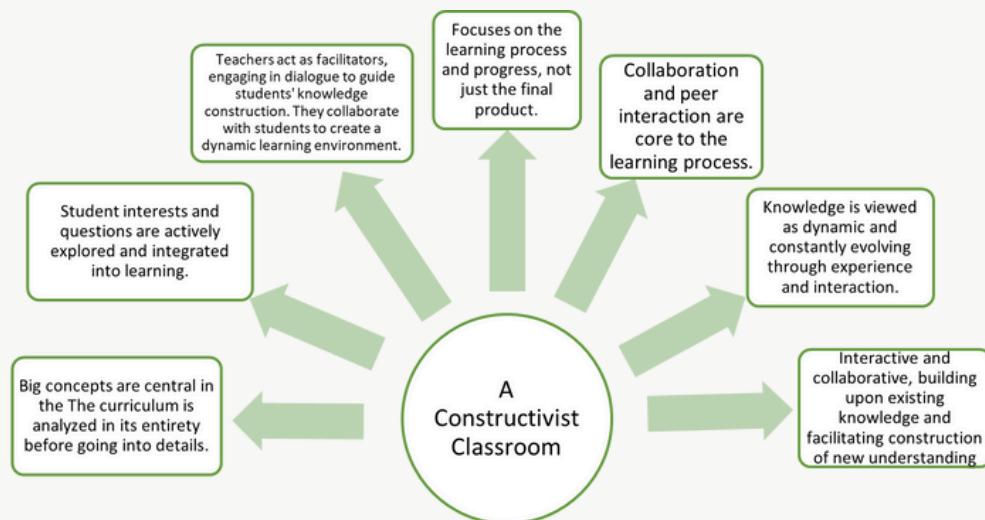


Theoretical Framework - III

3- Constructivist learning - education should be student-oriented

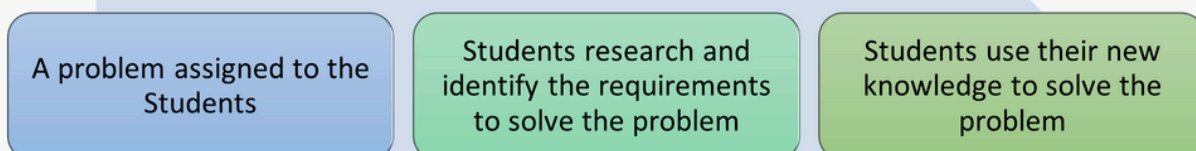
In constructivist theory, learners do not take in knowledge passively but instead construct it. Learners experience the world and then reflect on these experiences to create their own schema and incorporate new information into their pre-existing knowledge.

A constructivist classroom is characterized by a student-centred approach that values inquiry, hands-on experiences, collaboration, and a dynamic understanding of knowledge. Teachers play a facilitative role, guiding students to construct their own understanding through interactive processes. Assessment methods reflect a holistic view of learning that emphasizes both the journey and the destination.



4- Problem-based learning - Students must solve a problem to learn a subject

Problem-based learning (PBL) is a student-centered pedagogy in which students learn about a subject through the experience of solving an open-ended problem found in trigger material. The PBL process does not focus on problem solving with a defined solution, but it allows for the development of other desirable skills and attributes. This includes knowledge acquisition, enhanced group collaboration and communication. In PBL classes students learn about a subject by working in groups to solve the problem.



Theoretical Framework - IV

M-STEM pedagogy involves all these aforementioned educational approaches and combines them in a virtual reality environment. The MSTEM platform allows teachers to assign questions to students in a virtual environment. Students can access information about the question using the resources provided on the MSTEM platform. Students can be divided into groups and do group work in the virtual environment. The teacher is involved in the groups as a facilitator and helps students find the solution to the problem. Students learn STEM subjects interactively thanks to the 3D objects, animations and real-time interactions offered on the MSTEM platform.

Interactive Applications of a M-STEM Course

The integration and use of virtual reality technology enhances student success and learning STEM subjects. MSTEM pedagogy offers a variety of interactive tools to enhance STEM learning; virtual simulations, 3D objects, virtual experiments, collaborative tools, and gamification elements designed specifically for teaching STEM subjects (Science, Technology, Engineering, and Mathematics).

Interactive Learning Environment

MSTEM pedagogy involves an interactive learning environment. The virtual learning environment to be designed and developed within the scope of the MSTEM project will serve as a STEM laboratory for students. This Virtual Lab will include various learning tools for students and teachers. STEM teachers can use 3D objects and animations to allow students to interact with new materials and experience them intensively, while virtual experiments can provide interactive learning opportunities in a safe environment.

Collaborative Tools

The MSTEM virtual lab also features collaborative tools. With the help of these tools, students can conduct an experiment together or discuss STEM topics. These collaborative tools also allow for interactive learning and problem solving through trial and error while exploring realistic 3D objects. The interactive tools offered by the MSTEM platform allow teachers to interact with students during the learning process, which is important for problem-based and student-centred learning.

MSTEM Lab acts as an activity centre for STEM lessons by creating a virtual classroom. On this platform, teachers can create virtual "classes" of specific students and distribute assignments or educational materials to all students in each class. Students can submit their work through this platform and teachers can access it in real time, present it in the virtual classroom, comment on it and edit it if necessary.

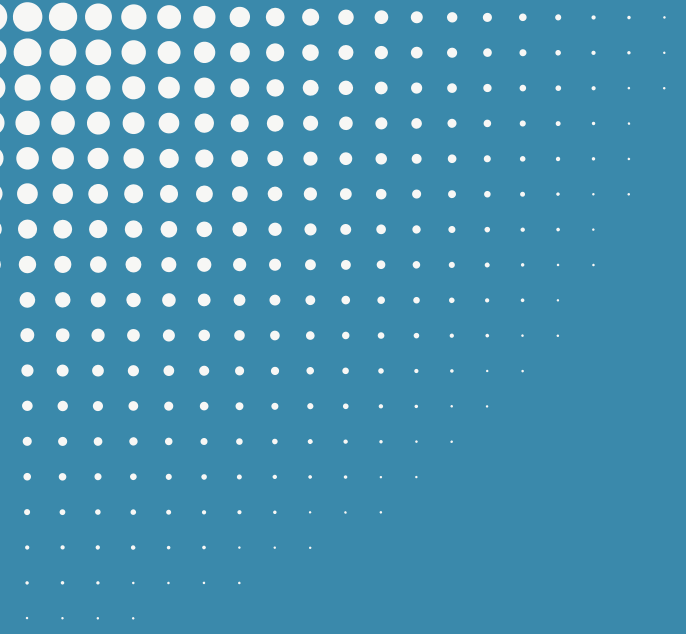
Simulations

In the MSTEM lab, simulations can be used to observe moving objects, such as spinning wheel systems, or to explore natural phenomena that occur over long periods of time, such as the water cycle. It is believed that using simulations in the classroom can help to enhance learning. Simulations are designed to help enhance student STEM learning. Today, simulations are widely used in classroom settings for educational purposes.

Conclusions

MSTEM VR Lab platform offers a realistic STEM lab experience that students and teachers can access to perform experiments in a risk-free environment. The MSTEM VR lab has opportunities and tools that are not available in real labs, such as zooming in to view 3D objects at a micro level and changing time to make experiments faster. Lab simulations can be used for immersive STEM lessons. MSTEM VR also provides a space for creativity and innovation. By changing the laws of physics, students can uncover new processes and lead to brand new discoveries.

Today's students are different from students of the past because of their ability to use technology and therefore have different learning processes and goals. This requires different teaching approaches. VR classrooms, designed with the teacher and students in mind and with attention to the learning content, offer a unique opportunity for teaching STEM subjects. In MSTEM VR pedagogy, teachers have an important role as mediators of digital learning experiences. While the resources available for teachers and students are of high quality, it is critical to evaluate them for curricular relevance, effectiveness, and appropriateness for classroom conditions. Therefore, teachers are an indispensable part of MSTEM pedagogy.



Chapter 2

Integrating STEM with Digital Technology

By VAEV R&D

Understanding the Digital Landscape in STEM Education

The Role of Digital Technology

Digital technology serves as a transformative force in the realm of STEM education, revolutionizing traditional teaching methods and opening up new dimensions of learning. Its role is multifaceted, offering a range of tools and resources that go beyond the confines of traditional textbooks and lectures.

Enabling Virtual Simulations

One of the primary contributions of digital technology is the facilitation of virtual simulations. These simulations provide students with the opportunity to engage with complex scientific concepts in a controlled and dynamic environment. For instance, in physics, students can explore gravitational forces through interactive simulations, enhancing their understanding by visually and interactively experiencing abstract theories.

Empowering Interactive Applications

Digital tools empower educators to create interactive applications that cater to diverse learning styles. Whether through gamified quizzes, interactive presentations, or virtual experiments, teachers can employ applications that captivate students' attention and stimulate their curiosity. This not only makes learning more engaging but also reinforces key STEM concepts through hands-on experiences.

Overcoming Physical Limitations

Digital technology transcends physical barriers in education. Students can delve into intricate biological processes, explore the depths of outer space, or conduct chemical experiments without the limitations of physical space, equipment, or safety concerns. This aspect of technology ensures that every learner has access to experiences that might otherwise be logistically challenging.

Understanding the Digital Landscape in STEM Education - I

Real-world Applications

Integration of digital tools allows for the exploration of real-world applications of STEM concepts. Through augmented reality, for instance, students can overlay digital information onto the physical world, offering insights into how STEM principles are applied in various industries. This connection to real-world scenarios enhances the relevance and practicality of STEM education.

Digital Competencies for Educators

To harness the full potential of digital technology in STEM education, educators must cultivate digital competencies that extend beyond basic technological literacy. Proficiency in leveraging various digital tools is essential for creating a rich and dynamic learning environment.

Virtual Reality (VR)

Virtual reality (VR) is simulated experience that employs pose tracking and 3D near-eye displays to give the user an immersive feel of a virtual world. It is mainly used for games, and this makes it interactive when teaching children. Teachers with digital competencies can utilize VR to transport students to virtual laboratories, allowing them to explore STEM subjects in an immersive 3D space. Understanding how to integrate VR into lesson plans enhances educators' ability to provide unique and memorable learning experiences.

Collaboration through Digital Platforms

Digital competence extends to collaborative tools that facilitate communication and teamwork. Educators well-versed in these tools can encourage collaborative problem-solving, discussions, and project work among students, mirroring real-world STEM environments where teamwork is crucial.

Aligning STEM Objectives with Digital Tools

Clarity in Educational Goals

Before delving into the integration of digital tools, it is imperative for educators to have a clear understanding of the learning objectives within the STEM curriculum. These objectives serve as the foundation for selecting appropriate tools and technologies. Clarity in educational goals enables teachers to map out the desired outcomes and identify areas where digital tools can enhance the learning experience.

Tailoring Digital Integration

Identification of learning objectives allows for the customization of digital tool integration. By aligning each tool with specific learning goals, educators can create a cohesive and purposeful educational experience. For instance, if the objective is to understand complex biological processes, selecting digital tools that offer detailed simulations or virtual dissections becomes crucial.

Assessment Alignment

Learning objectives also play a pivotal role in shaping the assessment strategies. Educators can design assessments that align with the identified objectives, ensuring that the integration of digital tools contributes directly to the evaluation of student understanding. This holistic approach ensures that the use of technology enhances both the learning and assessment aspects of STEM education.

Digital Tools



Virtual Simulations

Virtual simulations stand as dynamic tools that can cater to various STEM disciplines. Whether it's physics experiments, chemical reactions, or engineering prototypes, virtual simulations offer a risk-free environment for students to explore and apply theoretical concepts. The selection of specific simulations should align with the identified learning objectives, providing students with immersive experiences directly related to the curriculum.

Augmented Reality (AR)

Augmented reality (AR) is an interactive experience that combines the real world and computer generated content. What is the difference between VR and AR? Virtual reality immerses users in entirely digital environments, while augmented reality overlays digital content onto the real world. Incorporating augmented reality into STEM education adds a layer of real-world application to theoretical concepts. AR enables students to overlay digital information onto physical objects, creating interactive and engaging learning experiences. The choice of AR applications should be guided by the need to connect abstract theories with tangible, real-world scenarios, aligning seamlessly with the MSTEM pedagogical strategy.

Customization for MSTEM Pedagogy

Considering the unique aspects of the MSTEM pedagogical strategy, the selection of digital tools should be customized to align with its learner-centred approach. Tools that empower students to actively engage, explore, and construct knowledge within virtual environments resonate with the principles of MSTEM. The ability to customize tools ensures that they not only meet general STEM objectives but also enhance the specific goals outlined in the MSTEM framework.

Accessibility and Enjoyment

When choosing digital tools, educators should prioritize accessibility and enjoyment. The selected tools should be easily accessible to all students, ensuring inclusivity. Moreover, the tools should foster enjoyment, as the MSTEM strategy recognizes the importance of fun and engagement in the learning process. Tools that captivate students' interest contribute significantly to the overall success of MSTEM pedagogy.

Digital Tools



Virtual Simulations

Virtual simulations stand as dynamic tools that can cater to various STEM disciplines. Whether it's physics experiments, chemical reactions, or engineering prototypes, virtual simulations offer a risk-free environment for students to explore and apply theoretical concepts. The selection of specific simulations should align with the identified learning objectives, providing students with immersive experiences directly related to the curriculum.

Augmented Reality (AR)

Augmented reality (AR) is an interactive experience that combines the real world and computer generated content. What is the difference between VR and AR? Virtual reality immerses users in entirely digital environments, while augmented reality overlays digital content onto the real world. Incorporating augmented reality into STEM education adds a layer of real-world application to theoretical concepts. AR enables students to overlay digital information onto physical objects, creating interactive and engaging learning experiences. The choice of AR applications should be guided by the need to connect abstract theories with tangible, real-world scenarios, aligning seamlessly with the MSTEM pedagogical strategy.

Customization for MSTEM Pedagogy

Considering the unique aspects of the MSTEM pedagogical strategy, the selection of digital tools should be customized to align with its learner-centred approach. Tools that empower students to actively engage, explore, and construct knowledge within virtual environments resonate with the principles of MSTEM. The ability to customize tools ensures that they not only meet general STEM objectives but also enhance the specific goals outlined in the MSTEM framework.

Accessibility and Enjoyment

When choosing digital tools, educators should prioritize accessibility and enjoyment. The selected tools should be easily accessible to all students, ensuring inclusivity. Moreover, the tools should foster enjoyment, as the MSTEM strategy recognizes the importance of fun and engagement in the learning process. Tools that captivate students' interest contribute significantly to the overall success of MSTEM pedagogy.

Practical Implementation Strategies

Virtual Environment Creation

Creating immersive learning experiences involves the strategic design of virtual environments that align with the MSTEM pedagogical strategy. Teachers should consider the following:

- *User-Centered Design*: Tailor virtual environments to cater to the diverse learning styles and preferences of students. Ensure that the design fosters engagement, enjoyment, and alignment with STEM learning objectives.
- *Goal Setting*: Clearly define learning goals within the virtual environment. Establish objectives that resonate with MSTEM principles, promoting self-directed learning, autonomy, and collaborative knowledge construction.
- *Structured Activities*: Design activities that encourage exploration, experimentation, and problem-solving. Integrate challenges that mimic real-world scenarios, allowing students to apply STEM concepts in practical situations.
- *Teacher as Guide*: Emphasize the role of the teacher as a guide within the virtual environment. Teachers should actively participate in designing activities, setting goals, and providing guidance while allowing students the freedom to explore and construct knowledge.

Assessment Integration

Assessment strategies should seamlessly integrate with immersive learning experiences:

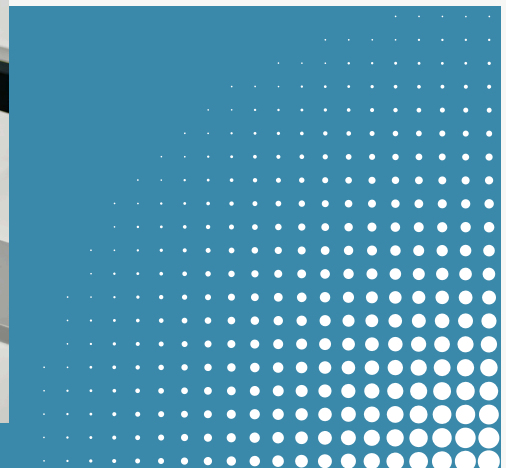
- *Authentic Assessment*: Design assessments that reflect real-world applications of STEM knowledge. This could include project-based assessments, virtual experiments, and collaborative problem-solving tasks.
- *Progress Monitoring*: Implement tools within the virtual environment for real-time progress monitoring. This allows teachers to gauge individual and collective understanding, providing timely feedback to enhance the learning process.
- *Reflection Opportunities*: Integrate reflection components within activities, encouraging students to articulate their learning experiences. This self-reflection fosters metacognition and a deeper understanding of STEM concepts.

Collaborative Learning in a Digital Space

Utilizing Collaborative Tools

Digital platforms offer a plethora of collaborative tools. Strategies for effective use include:

- **Virtual Classrooms:** Establish virtual classrooms within the MSTEM framework, providing spaces for group collaboration. Teachers can assign tasks, share resources, and facilitate discussions within these digital classrooms.
- **Project-Based Collaboration:** Encourage project-based collaborative learning. Assign tasks that require teamwork, problem-solving, and the application of STEM principles. Digital platforms should support seamless collaboration, allowing students to work together irrespective of physical locations.
- **Interactive Discussions:** Leverage digital tools to facilitate interactive discussions. Incorporate forums, chat features, or video conferencing to promote dialogue among students. Teachers can moderate and guide discussions, ensuring that collaborative learning extends beyond physical classrooms.



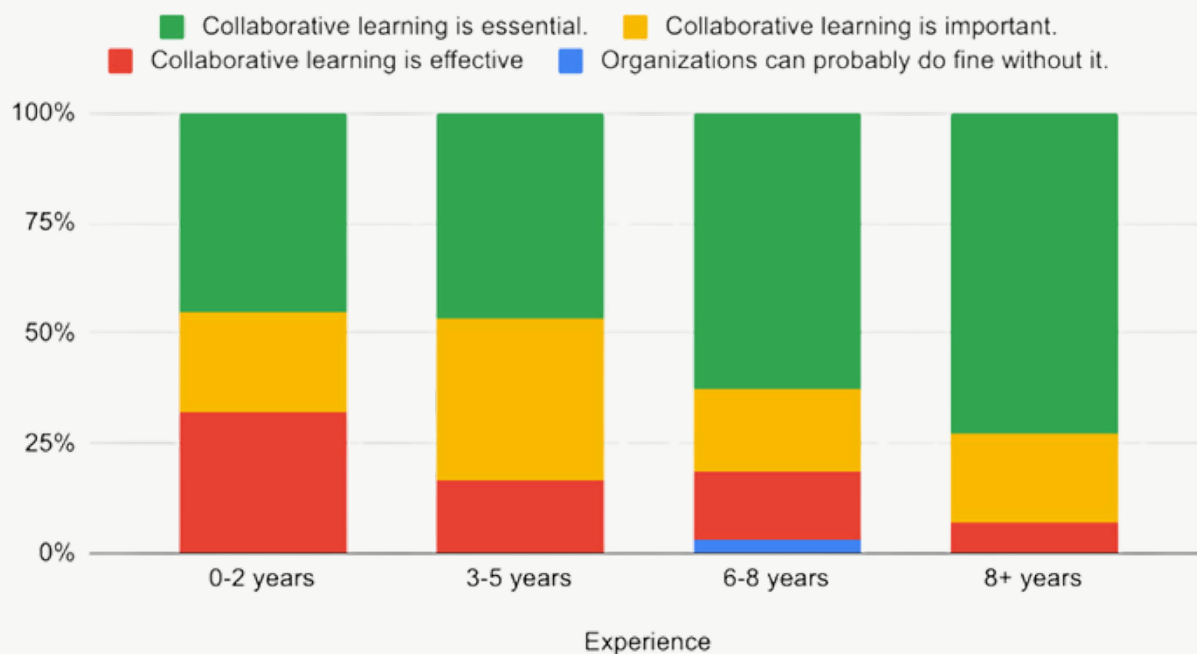
Collaborative Learning in a Digital Space - I

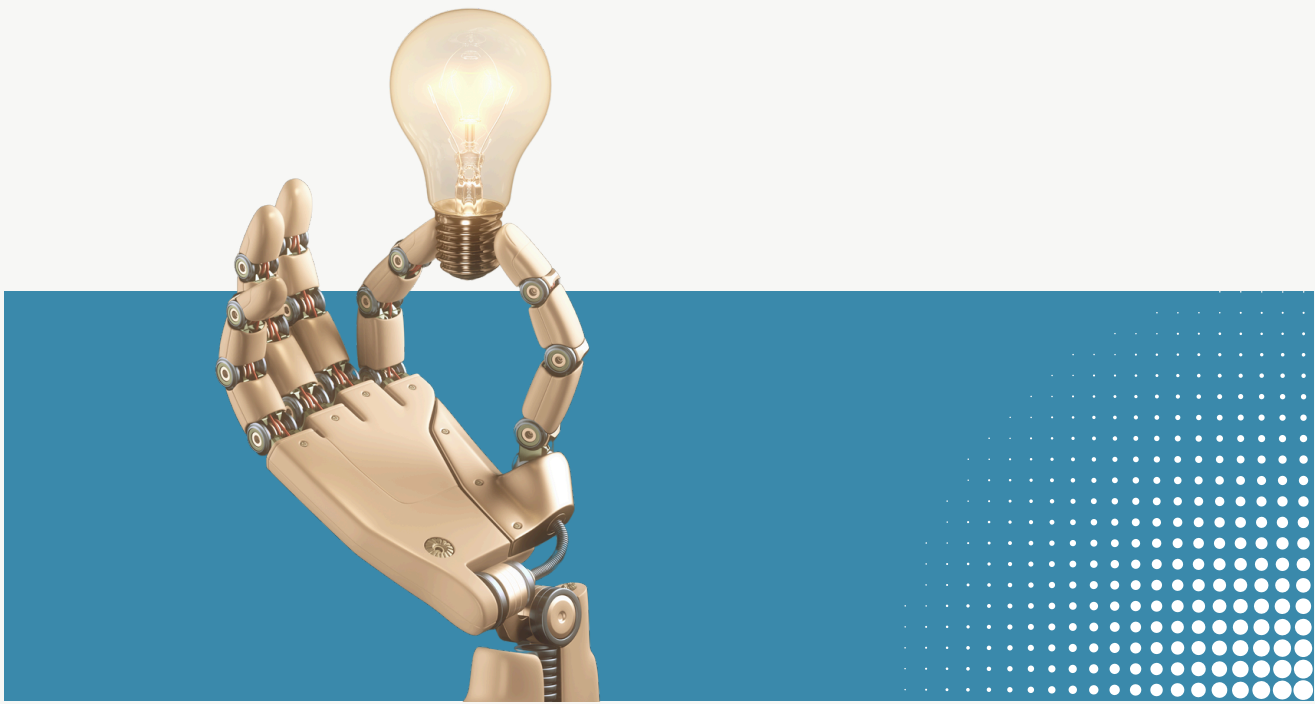
Facilitating Group Activities

Teachers can employ strategies to effectively manage group activities in a digital space:

- *Clear Instructions*: Provide clear instructions for group activities, outlining roles and responsibilities. Virtual collaboration should mirror the structure of in-person group work, ensuring that each student contributes meaningfully.
- *Feedback Mechanisms*: Implement feedback mechanisms within digital platforms. Encourage peer feedback and provide opportunities for teachers to assess group dynamics and individual contributions.
- *Adaptability*: Foster adaptability within groups. Digital collaboration may require adjustments, and teachers should guide students in navigating challenges and leveraging technology for effective teamwork.

How important is collaborative learning?





Addressing Technology Barriers

Access to Technology

- *Equity Considerations:* One of the primary challenges in digital integration is ensuring equal access to technology for all students. Recognizing the digital divide, educators should collaborate with school administrators to identify and address disparities in device availability and internet connectivity.
- *Resource Allocation:* Seek funding or leverage community partnerships to allocate resources for students lacking access to necessary devices. Implement initiatives like device lending programs or community Wi-Fi access points to bridge the technology gap.
- *Offline Alternatives:* Develop contingency plans for students facing persistent connectivity issues. Provide offline resources, such as downloadable materials or alternative assignments, ensuring that learners can engage with STEM content irrespective of their online accessibility.

Technical Issues

- *Technical Support Systems:* Establish robust technical support systems to address issues promptly. Collaborate with IT departments or enlist the assistance of technology-savvy students to create a support network. Clear communication channels for issue reporting and resolution should be readily available.
- *Training for Technical Proficiency:* Equip both educators and students with basic troubleshooting skills. Offer training sessions or tutorials on common technical challenges to empower the learning community in resolving minor issues independently.
- *Redundancy Plans:* Develop redundancy plans for critical activities. In instances where a specific digital tool or platform encounters technical problems, having alternative resources or platforms ensures uninterrupted learning experiences.

Conclusion

The conclusion from Module 2 emphasizes the importance of integrating STEM education with digital technology to enhance learning experiences. It highlights digital technology's transformative role in reshaping traditional teaching methods, offering educators insights, strategies, and practical guidance to seamlessly merge STEM education with digital capabilities. Digital tools, such as virtual simulations and augmented reality, empower students to engage with complex concepts and overcome physical limitations, ensuring inclusivity and accessibility.

Educators are encouraged to develop digital competencies and align STEM objectives with appropriate tools, tailoring integration to enhance learning outcomes. Practical implementation strategies, including virtual environment creation and assessment integration, are outlined to facilitate immersive and collaborative learning experiences. Additionally, the chapter addresses technology barriers, emphasizing equity considerations, technical support systems, and training for technical proficiency to ensure equal access and smooth implementation of digital integration in STEM education.



Chapter 3

Creating Immersive and Interactive Learning Experiences

By Eurasia

Introduction



Today students are born into a digital world and technology is an inseparable part of their lives. Therefore, today's students find it difficult to respond to traditional education methods. In other words, the digital lifestyles of young people cause traditional education methods to blend with technology and transform according to new needs. To meet their needs, education is shifting from passive knowledge acquisition to active participation. Because today's generation needs new pedagogical approaches. Educators must keep up with this change and integrate technology into the classroom. Using virtual reality classrooms is one of the most effective ways to achieve this.

Immersive learning has emerged as a strategy that uses virtual reality technology to deliver engaging and dynamic learning experiences. Immersive learning replaces traditional lectures and textbooks with simulated virtual environments, 3D simulation of the real world, and group interactions, allowing students to explore, experiment, and produce knowledge in a dynamic and engaging way. This new opportunity led to a change in our understanding of education and changed our perspective.

Immersive learning can involve the application of different strategies. These include gamification, story-based learning, video-based learning, or scenario-based learning, branching simulations, Augmented Reality (AR), Virtual Reality (VR), Extended Reality (XR) and Mixed Reality (MR).

Virtual Reality (VR) refers to a fully simulated digital environment in which users are immersed using VR headsets to create believable experiences. These experiences can be a real-life situation or a creative, imaginary experience.

Augmented Reality (AR) combines digital content on top of the real world through a phone, glasses, or a headset.

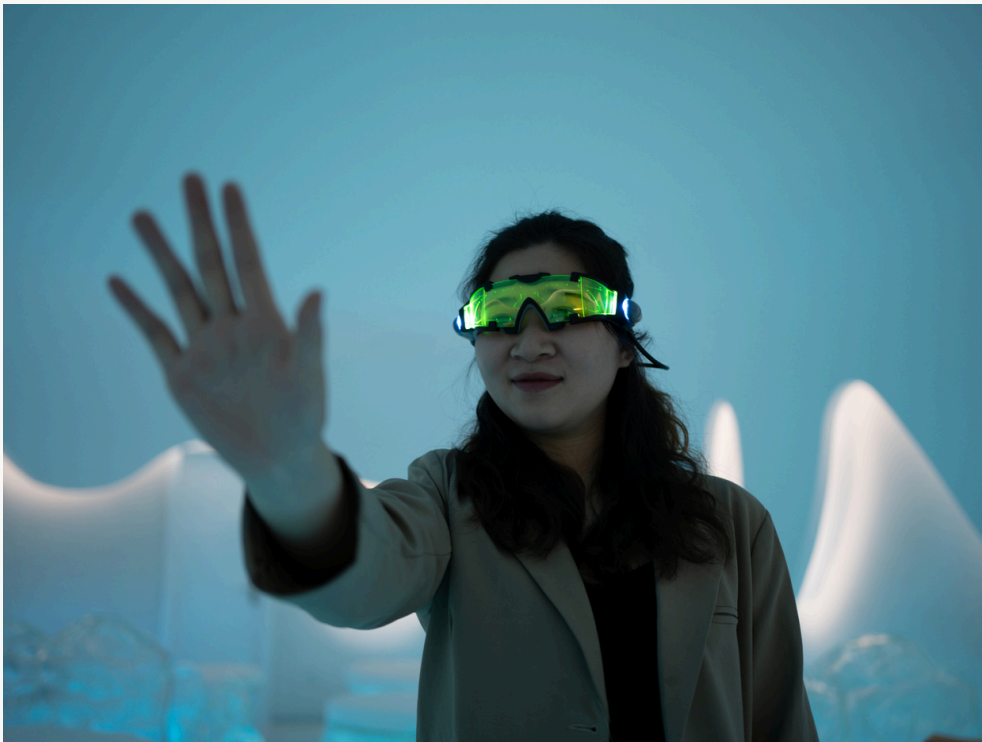
Mixed Reality (MR) mixes digital and real objects. Users can interact with each other in real time. In MR, virtual objects are integrated into the real-world environment for completely realistic experiences.

Extended Reality (XR) refers to the coexistence of integrated real and virtual environments and human-machine interactions. In other words, AR, VR and MR coexist in Extended Reality.

What is Immersive Learning?

Virtual Reality is a computer-generated simulation of a three-dimensional environment. Users can interact with this three-dimensional environment using specialized hardware such as VR headsets or controllers.

VR technology blurs the lines between the physical and virtual worlds and immerses users in a realistic experience. This immersive environment created using VR allows students to feel the virtual environment and its objects as real.

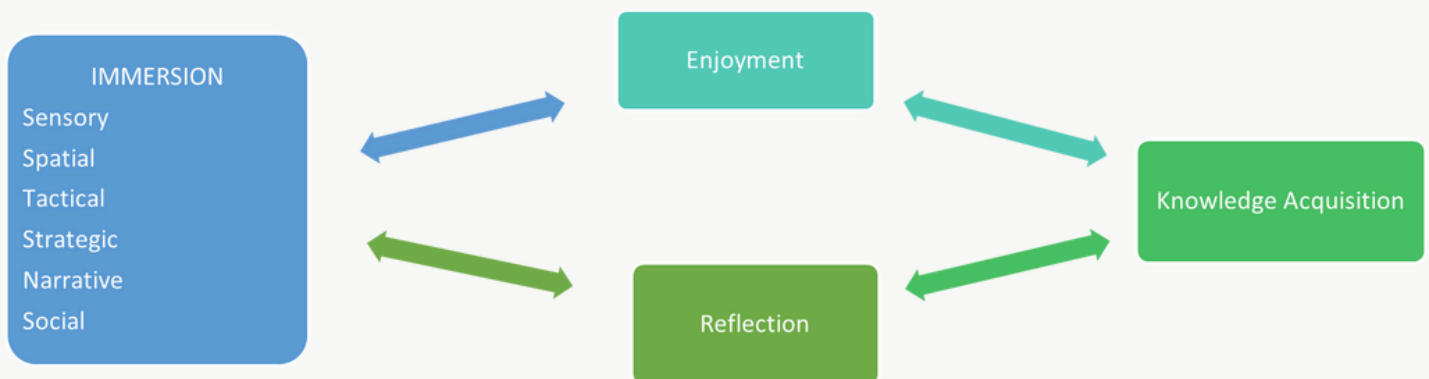


How can you design an interactive learning experience with VR?

There are different types of immersion:

- Sensory
- Spatial
- Tactical
- Strategic
- Imaginative
- Social

It would be a good idea to use several of these immersion types together to create an effective immersive learning space. Multiple use of immersion will help users to engage more in the target subject. Of course, the type of immersion can be chosen in line with the pedagogical approach and the requirements of the topic, however, sensory, and spatial immersions are the most engaging ones for users. The following graphic provided by C. Wagner and L. Liu (Liu et al. 2017) clearly shows the learning cycle through the immersive learning environments.



Designing Immersive Learning Experiences



While designing an immersive learning experience its important to know the types of immersion.

As it is previously mentioned there are different types of immersion and the teacher or the designer should choose the most relevant and engaging type to facilitate knowledge acquisition. In the simplest terms, virtual reality immersion is the feeling that a person is physically present in a virtual environment. Graphics and sounds can be used to create this feeling. Other sensory feedback can also be used, such as the vibration of hand controllers when one's avatar touches an object in the virtual environment or the scent of the environment.

Types of Immersion



Sensory Immersion

Sensory immersion allows users to feel themselves in an immersive environment by using tools that appeal to our senses, such as graphics and sounds. With sensory stimulation targeting your senses of sight, hearing, touch, smell and taste, it allows you to feel yourself in a real environment.



Spatial Immersion

Spatial immersion refers to the type of immersion triggered and sustained by the spatial qualities of the virtual environment (Zhang, C. et al 2017). In spatial immersion, the immersive effect of the virtual environment can be achieved by manipulating different spatial elements of the scene. Fast zooming in and out, suddenly changing camera angles may help to create spatial immersion feeling.



Tactical Immersion

"Tactical immersion is experienced when performing tactile operations that involve skill. Players feel "in the zone" while perfecting actions that result in success".

Types of Immersion



Strategic Immersion

“Strategic immersion is more cerebral, and is associated with mental challenge. Chess players experience strategic immersion when choosing a correct solution among a broad array of possibilities”.



Imaginative Immersion

Another way to dive into your imagination is to become emotionally connected to the story or characters you are creating. This is like really getting into a film or book. You can imagine yourself in the place of a character in the film or story and get excited, scared, sad or happy, as if you were the one experiencing all the action.

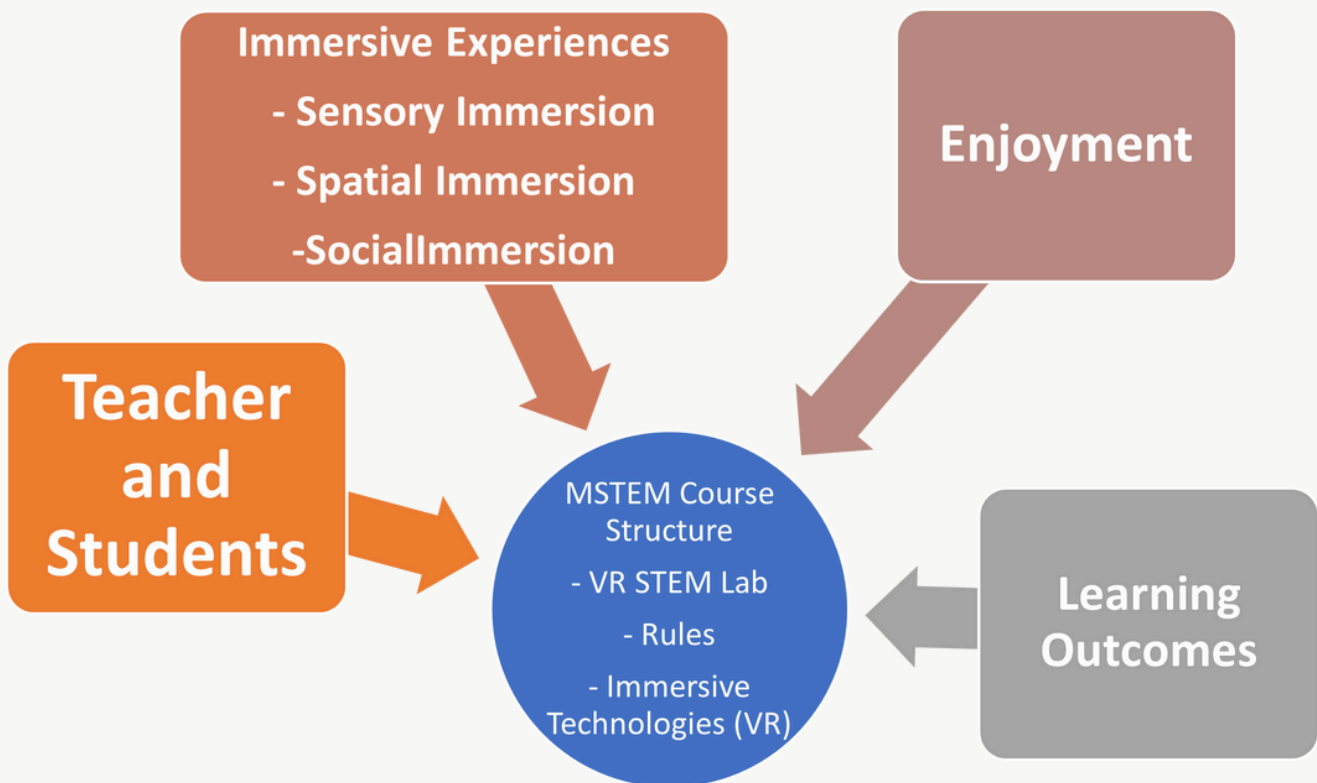


Social Immersion

It means actively engaging with a social group or community that you would not normally be part of. Many universities and educational institutions offer social immersion programmes specifically designed to educate students about certain social issues.

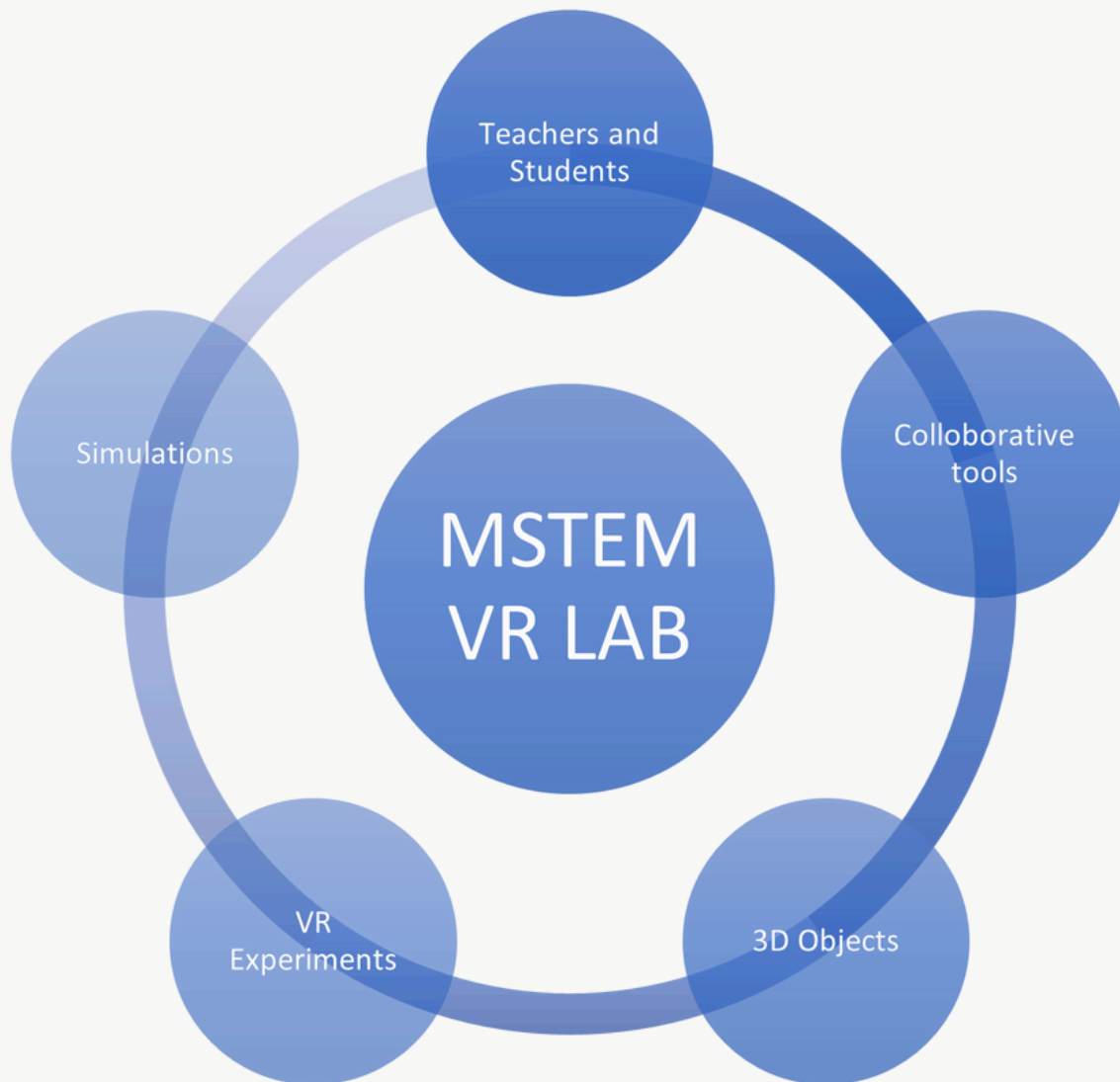
What are the elements of Immersive Learning Experiences of MSTEM course?

As it is mentioned earlier, the key to a successful Immersive Learning Experience design lies in choosing the right type of immersion and implementing it effectively. For MSTEM we will use sensory, spatial, and social immersion types. The graphic below shows the structure and immersive Learning Experience elements of MSTEM course.



VR STEM Lab as an Interactive Learning Environment

MSTEM VR Lab will be our main interactive learning space. Different elements will be used to create an interactive learning environment in MSTEM VR Lab. These elements will be supported by different elements to create a sense of sensory, spatial, and social immersion. Here we will go through these elements one by one.



STEM Lab Environment for Sensory Immersion and Spatial Immersion

MSTEM VR Lab will include some immersive elements to create sensory immersion feeling. A 360-degree space where the students can observe their environment will make them feel in a real lab and interacting with objects using VR gears will stimulate their sense of touch. Visual aids will also be used to appeal to the visual senses. 3d models of STEM objects can be presented by the teacher and the students will interact with these objects.

Collaborative Tools for Social Immersion

The MSTEM VR LAB also supports students to interact and work in groups. Under the supervision of the teacher in the VR LAB, students will be able to work collaboratively on a project, experiment or simulation and act together while completing a task. This will create social immersion.

Simulations

Simulations of STEM experiments will support the sense of reality. With the help of experiment simulations, students can have the opportunity to experience scenarios that they cannot experience in real life. For example, an experiment that can be performed in a nongravity environment can be easily performed in VR STEM Lab. By controlling gravity, students can observe the living conditions on different planets. Another simulation example is that experiments that need to be done in a time-dependent manner (such as fossilisation process, water cycle) can be carried out in a short time in VR STEM Lab. All these elements will enable the student to enjoy the process and encourage the student's active participation in the lesson.

In MSTEM VR LAB students can visit other planets or galaxies, climb the mount Everest or explore the ocean. Possibilities are limited to your imaginations.

The VR Experiments

MSTEM VR LAB allow students to do many experiments. Students spend less time to do simulated VR experiments than they spend for physical ones. VR helps students to learn more about the STEM topics in a 3D environment.

STEM Lab Environment for Sensory Immersion and Spatial Immersion - I

Virtual classrooms facilitate access to experiments and applications that are normally difficult to see physically. Experiments that require a long time to finalise and can be done by creating special environmental conditions can be easily done in a VR environment. There are some advantages of conducting STEAM experiments in VR environments. Students can repeat the processes until they fully understand the process and excel at the targeted skill. Unlike physical experiments, VR experiments prevent students from being harmed. Physical damages that may occur as a result of incorrectly conducted experiment processes are prevented.

The 3D objects provided and the use of simulations in the experiments, which offer the possibility of detailed examination, enable students to realise the exact skill to be taught. The MSTEM VR LAB environment, which offers the opportunity to work as a team throughout this whole process, allows students to complete the learning process by having fun.

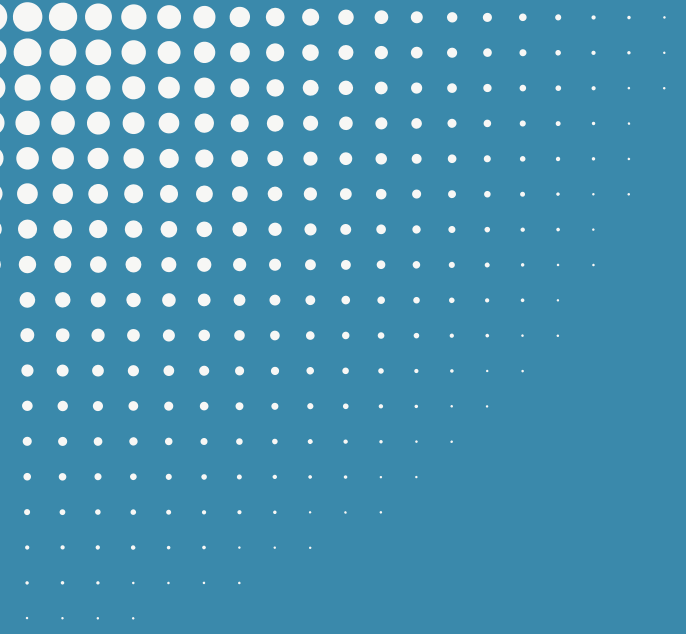
Conclusions

Immersive learning, powered by virtual reality, revolutionize education by taking students beyond the limits of textbooks and classrooms. With the ability to use multiple immersion types – sensory, spatial, social, and more – VR environments create compelling experiences that engage learners on a deeper level.

Key aspects of designing immersive learning experiences are understanding the different types of immersion to implement them effectively within MSTEM courses. The MSTEM VR Lab is a great example of how sensory immersion through 3D environments, spatial immersion through interactive elements and social immersion through collaborative tools can be combined to promote deeper understanding and engagement.

By utilising the power of virtual reality, we can unlock a universe of possibilities in education. Imagine students conducting complex experiments on distant planets, climbing the peaks of Mount Everest or diving into the depths of the ocean - all within the safe and accessible setting of a virtual classroom. Only our imagination sets the boundaries. MSTEM VR LAB can unlock the full potential of learning in the virtual age.

We cannot ignore the transformative potential of immersive learning. This innovative approach should be embraced by teachers and educators.



Chapter 4

Pedagogical Approaches for the M-STEM Project

By Malmö Stad

Introduction

In the ever-evolving landscape of education, the emergence of the metaverse has introduced new possibilities and challenges that necessitate a thoughtful consideration of pedagogical approaches. The metaverse, a collective virtual space that intertwines the physical and digital realms, has become a dynamic arena for learning and collaboration. As educators explore the potential of this immersive and interconnected space, the importance of well-defined and well thought through pedagogical approaches cannot be overstated.

Pedagogical approaches provide the guiding principles and methodologies essential for designing effective and meaningful learning experiences within the metaverse. These approaches serve as the scaffolding upon which educators can build engaging, inclusive, and learner-centric environments. With the metaverse offering a diverse range of tools, from virtual reality simulations to social collaboration platforms, the application of pedagogical frameworks becomes instrumental in harnessing the full educational potential of this digital frontier.

Considering the multifaceted nature of the metaverse, pedagogical approaches play a crucial role in shaping how knowledge is imparted and acquired. They enable educators to leverage immersive technologies, foster collaborative learning experiences, and tailor educational content to individual needs. Moreover, pedagogical frameworks guide the integration of ethical considerations, ensuring responsible use of technology and promoting digital citizenship within the metaverse.

As stated already in the first chapter in this WP it is crucial to again raise the importance of social learning and how it should not be underestimated. Like any other tool the Metaverse can be used in many different ways but if we have learned anything from the use of new digital approaches and tools it is that what we need is to think things through, we need to collaborate and discuss with others, learn from and together with others in order to create and construct knowledge for how to effectively integrate this technology and structure courses in order to have successful immersive learning experiences. In chapter one it is said: “It should be noted that in this pedagogy enjoyment is considered a key indicator of learning effectiveness”.

In this era of rapid technological advancement, the significance of pedagogical approaches in the metaverse lies in their ability to bridge the gap between innovation and effective learning outcomes. As educators navigate this digital realm, thoughtful pedagogy ensures that the metaverse becomes not just a platform for information delivery, but a dynamic space that nurtures critical thinking, creativity, and the development of essential skills for the future. This exploration of pedagogical approaches within the metaverse marks a pivotal moment in educational evolution, where thoughtful design meets transformative technology to create a rich and meaningful educational experience for learners in the 21st century.

Why is it important to focus on pedagogical approaches?

Chen et al (2023, p1126) have been looking into research on Edu-Metaverse both its immense potential but also its challenges that needs to be taken seriously. As well as their results “showed that Metaverse has been increasingly popular in various areas (.../STEM education, art education, language education and special education) to promote collaborative learning , gameful experiences, PBL, social learning and simulated learning.” It is therefore important to learn about pedagogical approaches (some mentioned in the quote above) in order to be able to implement these methods in teaching. Further on (ibis) it is also stating that “Edu-Metaverse has been increasingly reported to facilitate the development of learners’ language, social, communicative, and 21st-century competences, for example, higher-order thinking, collaboration and problem solving”. Focusing not only on facts while teaching is important and while combining the development of competencies with learning specific subjects has been proven to be very successful. Cai et al (2022) are also opening another door to education by saying that the metaverse “will potentially bring about new changes in education and teaching”.

Focusing on pedagogical approaches in the metaverse is important for several reasons, as it aligns with the changing dynamics of education in the digital age. We here list some key reasons why it's crucial to emphasize pedagogical approaches in the metaverse:

Enhanced Engagement and Motivation: Leveraging pedagogical approaches in the metaverse can create immersive and interactive learning experiences. This heightened engagement can lead to increased motivation among students, as they are more likely to participate actively in the learning process.

Personalized Learning: The metaverse allows for more personalized and adaptive learning experiences. Pedagogical approaches that focus on individualized progress tracking and adaptive learning platforms can cater to the unique needs and learning styles of each student, promoting a more effective and efficient learning journey.

Global Collaboration and Inclusivity: Pedagogical approaches in the metaverse facilitate global collaboration, connecting students from different parts of the world. This fosters cultural exchange, diversity, and inclusivity, preparing learners for a globalized and interconnected world.

Why is it important to focus on pedagogical approaches? - I

Preparation for Future Technologies: Integrating pedagogical approaches in the metaverse prepares students for the future by exposing them to cutting-edge technologies. As the metaverse continues to evolve, students gain valuable skills in navigating digital spaces and using technology responsibly.

Real-world Application of Knowledge: Experiential learning, project-based learning, and immersive simulations within the metaverse allow students to apply theoretical knowledge in practical, real-world scenarios. This bridges the gap between academic learning and real-world application, making education more relevant.

Technological Literacy: Focusing on pedagogical approaches in the metaverse helps develop technological literacy among students. They not only learn subject-specific content but also gain proficiency in using digital tools, collaborating in virtual spaces, and navigating online environments responsibly.

Flexibility and Accessibility: Pedagogical approaches in the metaverse provide flexibility in terms of when and where learning can take place. This accessibility is particularly beneficial for learners who may face geographical or time constraints, promoting a more inclusive educational experience.

Data-Informed Teaching: The metaverse offers tools for tracking and analyzing student progress. Educators can leverage data-driven insights to tailor their teaching strategies, providing targeted support or challenges based on individual student needs.

Prevention of Digital Inequity: By focusing on pedagogical approaches in the metaverse, there is an opportunity to address and mitigate digital inequity. Ensuring that all students have access to technology and training in digital literacy promotes a more equitable learning environment.

Mystakidis (2022, p487) emphasises that “the Metaverse is based on technologies that enable multisensory interactions with virtual environments, digital objects and people./.../interaction in XR environments does not require users to be stationary. Users can activate their entire bodies.”

Why is it important to focus on pedagogical approaches? - II

These thoughts combined with different pedagogical approaches will be very useful for teachers who are creating alternative ways of teaching and learning. It will engage the students in different ways and the teacher can find multiple approaches to differentiate their teaching.

In essence, prioritizing pedagogical approaches in the metaverse is essential for creating a transformative and effective educational experience that aligns with the demands of the 21st century. It prepares students for a technologically advanced world, fosters critical skills, and cultivates a love for lifelong learning. At the same time as we are working on pedagogical approaches, we must keep in mind that there are challenges and risks attached to the Metaverse as well and these needs to be addressed parallel to the work with developing methods to enhance learning and raise the level of knowledge with the students.

Pedagogical Approaches in short:

The metaverse refers to a collective virtual shared space, merging the physical and virtual worlds, often accessed through the internet. Before we elaborate on the pedagogical approaches that this chapter will describe you will get a short summary of which ones they are and what they, connected to the metaverse, can achieve while implementing them:

In the metaverse, pedagogical approaches converge to redefine education, offering a dynamic and immersive landscape that transcends traditional boundaries. Through experiential learning, students engage in lifelike simulations and virtual experiences, bridging the gap between theory and practice. Immersive learning technologies, such as Virtual Reality (VR) and Augmented Reality (AR), enhance the educational journey, providing students with interactive 3D content and virtual scenarios for hands-on practice.

Collaborative learning thrives within virtual classrooms and social VR platforms, enabling global connections and fostering diverse perspectives. Students collaborate on projects, engage in interactive discussions, and build a sense of community beyond geographical limitations. Game-based learning integrates entertainment with educational objectives, leveraging the metaverse to create interactive and engaging experiences that enhance motivation and hands-on application of knowledge.

Blockchain technology, utilized for digital credentials, ensures the security and authenticity of achievements within the metaverse, offering decentralized and tamper-proof verification. Project-based learning utilizes virtual spaces for collaborative work, allowing students to showcase their projects and fostering creativity and teamwork. Cross-cultural exchanges promote global collaboration, connecting students worldwide for shared learning experiences and cultural exchange.

Digital literacy and ethics are integral components, teaching responsible use of technology, online etiquette, and ethical behaviour within the metaverse. Flipped learning, characterized by pre-recorded content, interactive discussions, and individualized progress tracking, combines self-paced learning with real-time engagement, providing a personalized and dynamic educational experience.



Experiential Learning

Experiential learning is an educational approach that emphasizes the importance of hands-on experiences in the learning process. It involves actively engaging students in real-world situations or simulations, encouraging them to reflect on and apply their knowledge in practical contexts. In the context of the metaverse, experiential learning can take on unique and immersive forms, such as virtual field trips and role-playing scenarios.

Virtual Field Trips

Definition: Virtual field trips involve using the metaverse to create simulated environments that replicate the experience of visiting different locations, such as historical landmarks, ecosystems, or cultural sites.

Implementation: Through virtual reality (VR) or other immersive technologies, students can explore these virtual environments as if they were physically present. They may interact with objects, receive information, and engage in activities that mimic the real world experience of a field trip.

Benefits:

- *Access to Distant Locations:* Virtual field trips allow students to "visit" places that might be geographically distant or difficult to reach, broadening their cultural and geographical understanding.
 - *Enhanced Engagement:* The immersive nature of virtual experiences can enhance student engagement and retention of information compared to traditional methods.
-



Experiential Learning

Role-Playing Scenarios

Definition: Role-playing scenarios involve creating simulated situations within the metaverse where students take on specific roles or personas. These scenarios often mirror real-world challenges, requiring students to make decisions, solve problems, and apply their knowledge in context.

Implementation: Students use avatars to represent themselves in the virtual environment, and they interact with other avatars or elements of the simulated scenario. The scenarios may be designed to reflect professional settings, historical events, or complex problem-solving situations.

Benefits:

- *Developing Critical Thinking:* Role-playing encourages students to think critically, analyse information, and make decisions based on the context of the scenario.
- *Applied Learning:* By immersing themselves in realistic situations, students can apply theoretical knowledge in a practical setting, bridging the gap between theory and practice.

- *Team Collaboration:* Many role-playing scenarios involve collaboration, fostering teamwork and communication skills as students work together to achieve common goals.

In both virtual field trips and role-playing scenarios, the metaverse provides a versatile platform for creating rich, interactive, and dynamic learning experiences. These approaches leverage technology to offer students opportunities for exploration, discovery, and application of knowledge in ways that extend beyond traditional classroom settings.



Immersive Learning

Immersive learning involves creating engaging and interactive educational experiences that deeply engage learners by simulating real-world environments or scenarios. The use of technologies like Virtual Reality (VR) and Augmented Reality (AR) as well as immersive simulations plays a key role in delivering these experiences. Here's an elaboration on each aspect:

Virtual Reality (VR):

Definition: VR refers to a computer-generated environment that simulates a three dimensional, immersive experience, often using a headset or special devices.

Implementation: In education, VR can transport students to virtual worlds that replicate real-life scenarios, historical events, or scientific concepts. For example, students studying astronomy could explore the solar system by virtually traveling through space.

Benefits:

- *Realism:* VR provides a high level of realism, enabling learners to feel as if they are physically present in the simulated environment.
 - *Engagement:* The immersive nature of VR captivates students' attention, enhancing focus and retention of information.
 - *Experiential Learning:* It allows for experiential learning by providing hands-on experiences that might be impractical or unsafe in the real world.
-



Immersive Learning

Augmented Reality (AR):

Definition: AR overlays digital information onto the real world, typically through devices like smartphones or AR glasses.

Implementation: AR in education might involve enhancing physical textbooks with interactive elements or placing virtual objects in the real environment. For instance, students studying anatomy could use AR to see 3D models of the human body superimposed on their textbooks.

Benefits:

- **Enhanced Learning Resources:** AR enriches traditional materials, making them more engaging and interactive.
- **Contextual Learning:** AR provides contextual information, allowing learners to connect theoretical concepts with real-world applications.

Immersive Simulations

Definition: Immersive simulations involve creating virtual scenarios that replicate real world situations to facilitate hands-on learning experiences.

Implementation: Educators can use immersive simulations for various purposes, such as virtual labs for scientific experiments, historical recreations for studying past events, or language immersion environments for practicing language skills.

Benefits:

- **Safe Experimentation:** Simulations offer a safe environment for learners to experiment and make mistakes without real-world consequences.
 - **Access to Inaccessible Environments:** Simulations provide access to environments that may be difficult or impossible to visit physically, such as historical settings or outer space.
 - **Personalized Learning:** Learners can engage in simulations at their own pace, allowing for individualized and self-directed learning.
-



Collaborative Learning

Collaborative learning involves fostering interactions and teamwork among students and educators, and in the context of the metaverse, it can take on new dimensions. Here's an elaboration on collaborative learning aspects:

Virtual Classrooms:

Definition: Virtual classrooms within the metaverse are online spaces that simulate traditional classrooms, allowing students and educators to interact in real-time using avatars.

Implementation: Educators can conduct lectures, discussions, and presentations in these virtual classrooms. Students, represented by avatars, have the ability for instance to participate in discussions, ask questions, and engage with course content.

Benefits:

- *Global Accessibility:* Virtual classrooms provide access to education for learners worldwide, overcoming geographical barriers.
 - *Real-time Interaction:* Students and educators can interact synchronously, fostering real-time engagement and communication.
 - *Immersive Learning Environment:* The metaverse adds an immersive layer to traditional online learning, creating a more engaging and dynamic environment.
-



Collaborative Learning

Social VR Platforms:

Definition: Social VR platforms are virtual spaces designed for social interaction, where users, represented by avatars, can communicate, collaborate, and engage in various activities.

Implementation: In education, social VR platforms facilitate collaborative learning experiences by allowing students to work together on projects, participate in group discussions, or attend virtual events.

Benefits:

- *Team Collaboration:* Students can collaborate on projects and assignments, fostering teamwork and interpersonal skills.
- *Networking Opportunities:* Social VR platforms provide opportunities for students to connect with peers, educators, and professionals, expanding their networks.

- *Multi-sensory Interaction:* Unlike traditional online communication, social VR platforms offer a more immersive and multi-sensory interaction, enhancing the sense of presence and connection.

Collaborative learning in the metaverse enhances traditional online education by providing a sense of presence and interactivity. It goes beyond text-based discussions and video conferences, offering students a more immersive and engaging experience. These collaborative learning environments in the metaverse aim to replicate the social aspects of traditional classrooms, fostering a sense of community and shared learning experiences among participants.



Game-based Learning

Game-based learning in the metaverse involves the integration of educational games designed within virtual environments to achieve specific learning objectives. Here's an elaboration on this concept:

Educational Games in the Metaverse

Definition: Educational games within the metaverse are interactive digital experiences designed to combine entertainment with educational objectives. These games are created within virtual environments to leverage the immersive and engaging nature of the metaverse for educational purposes.

Design Principles:

- *Alignment with Educational Objectives:* Games are designed to align with specific learning outcomes and educational goals. Whether it's teaching a particular subject, developing problem-solving skills, or reinforcing concepts, the game's design is closely tied to educational objectives.
 - *Interactivity and Engagement:* The metaverse allows for the creation of highly interactive and engaging game environments. Learners actively participate, make decisions, and navigate through challenges, promoting active learning.
 - *Storytelling and Narrative:* Educational games often incorporate compelling narratives and storylines to create an immersive learning experience. The storyline helps contextualize educational content and provides a meaningful context for learners.
-



Game-based Learning

- *Adaptability:* Games within the metaverse can be designed with adaptive features, adjusting the difficulty level based on the learner's progress. This personalization enhances the learning experience by catering to individual needs and pacing.
- *Feedback Mechanisms:* Immediate feedback is built into the game mechanics, allowing learners to understand the consequences of their decisions. Constructive feedback enhances the learning process and helps learners improve.
- *Collaborative Elements:* Some educational games in the metaverse may include collaborative elements, encouraging learners to work together to achieve goals, fostering teamwork and communication skills.

Examples of Educational Games in the Metaverse

- *Language Learning Games:* Interactive games that immerse learners in virtual environments where they practice and apply language skills through conversations, interactions, and challenges.
 - *Historical Simulation Games:* Games that allow learners to explore historical periods, make decisions in historical contexts, and understand the consequences of historical events.
 - *Math and Science Challenges:* Gamified environments where learners solve math problems or conduct virtual science experiments to reinforce mathematical and scientific concepts.
-

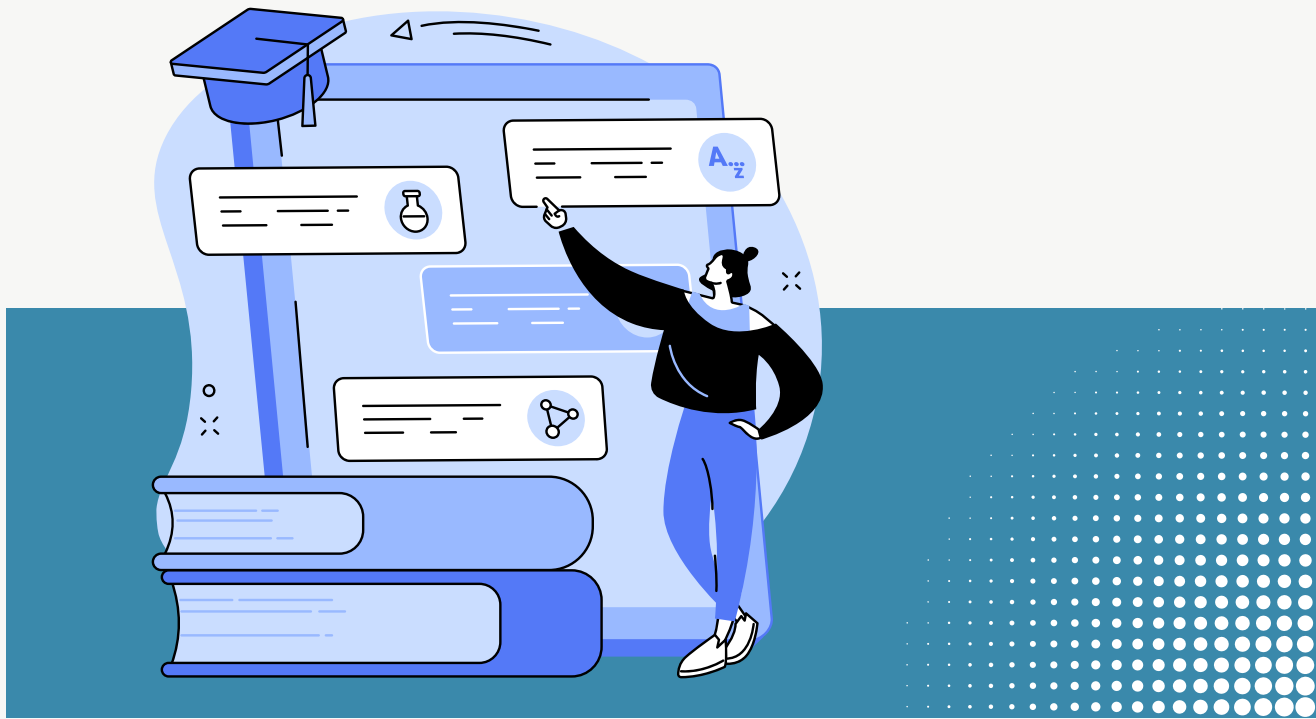


Game-based Learning

Benefits:

- *Increased Motivation:* The gamified elements within the metaverse capture learners' interest and motivation, making the educational experience more enjoyable.
- *Hands-On Application:* Games provide a hands-on approach to learning, allowing learners to apply theoretical knowledge in practical contexts.
- *Data Collection and Analytics:* Educational games in the metaverse can collect data on learners' interactions, progress, and decision-making, providing valuable insights for educators to tailor instruction.

Educational games in the metaverse offer a dynamic and interactive approach to learning, leveraging the immersive nature of virtual environments to enhance engagement and achieve educational objectives in a playful and enjoyable manner.



Personalized Learning

Personalized learning within the metaverse involves tailoring educational experiences to meet the individual needs, preferences, and progress of each student. One key aspect of personalized learning in the metaverse is the use of adaptive learning platforms, which leverage artificial intelligence (AI) to create customized learning paths. Here's an elaboration on this concept:

Adaptive Learning Platforms in the Metaverse

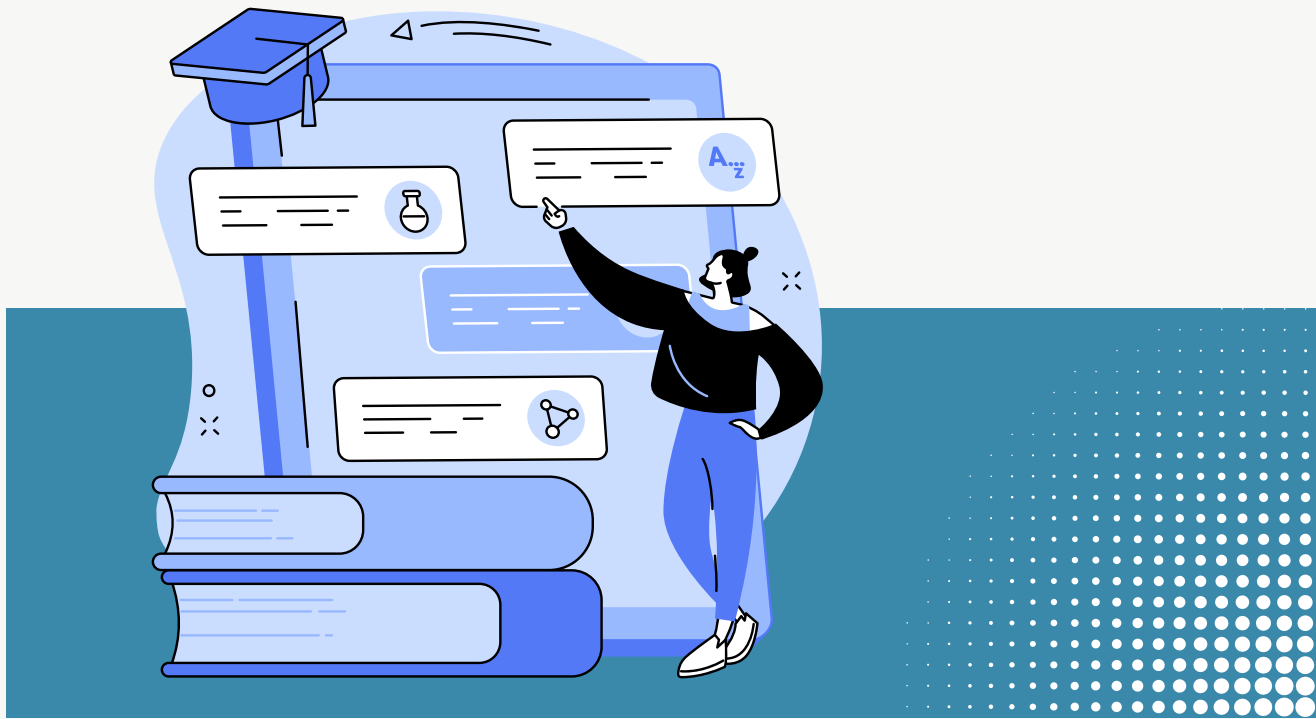
Definition:

Adaptive Learning: Adaptive learning platforms utilize AI algorithms to dynamically adjust the learning experience for each student based on their performance, preferences, and pace of learning.

Metaverse Integration: These platforms are designed to operate within the metaverse, leveraging the virtual environment to enhance the adaptability and personalization of the learning experience.

How Adaptive Learning Platforms Work in the Metaverse:

- *Assessment and Profiling:* Adaptive platforms start by assessing a student's existing knowledge, skills, and learning preferences. This could involve diagnostic assessments or initial surveys to understand the learner's baseline.
- *Real-Time Monitoring:* As students engage with content within the metaverse, the adaptive platform continuously monitors their interactions, progress, and performance. This real-time monitoring allows for immediate adjustments to the learning experience.

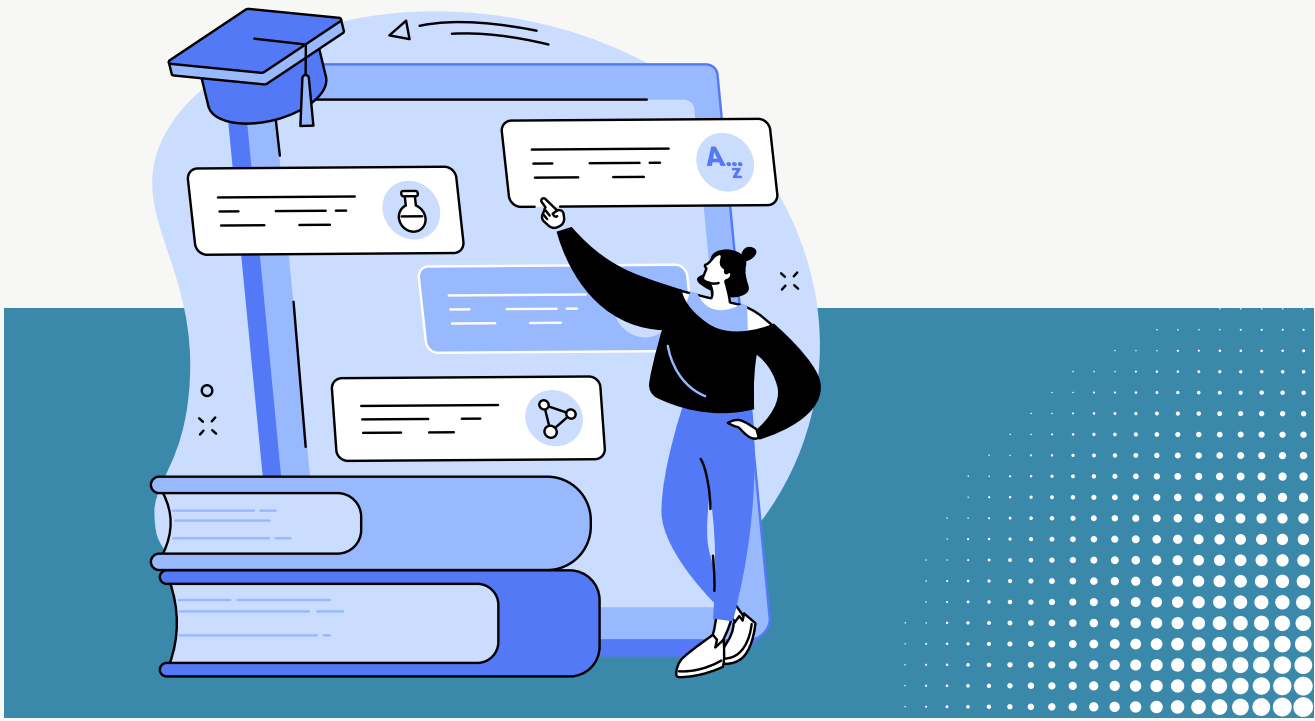


Personalized Learning

- *Personalized Content Delivery:* Based on the assessment and ongoing monitoring, the adaptive learning platform tailors the delivery of content. It may offer additional resources for areas where a student needs more support or accelerate progress in areas where the student demonstrates mastery.
- *Varied Learning Modalities:* Recognizing that different students have different learning styles, adaptive platforms may present information in various formats, such as videos, simulations, or interactive exercises, to cater to diverse learning preferences.
- *Feedback and Remediation:* Adaptive platforms provide timely and specific feedback to students, not only on correct or incorrect answers but also on the thought processes behind their responses. If a student struggles with a concept, the platform may offer remedial content or additional practice opportunities.

Benefits of Adaptive Learning Platforms in the Metaverse:

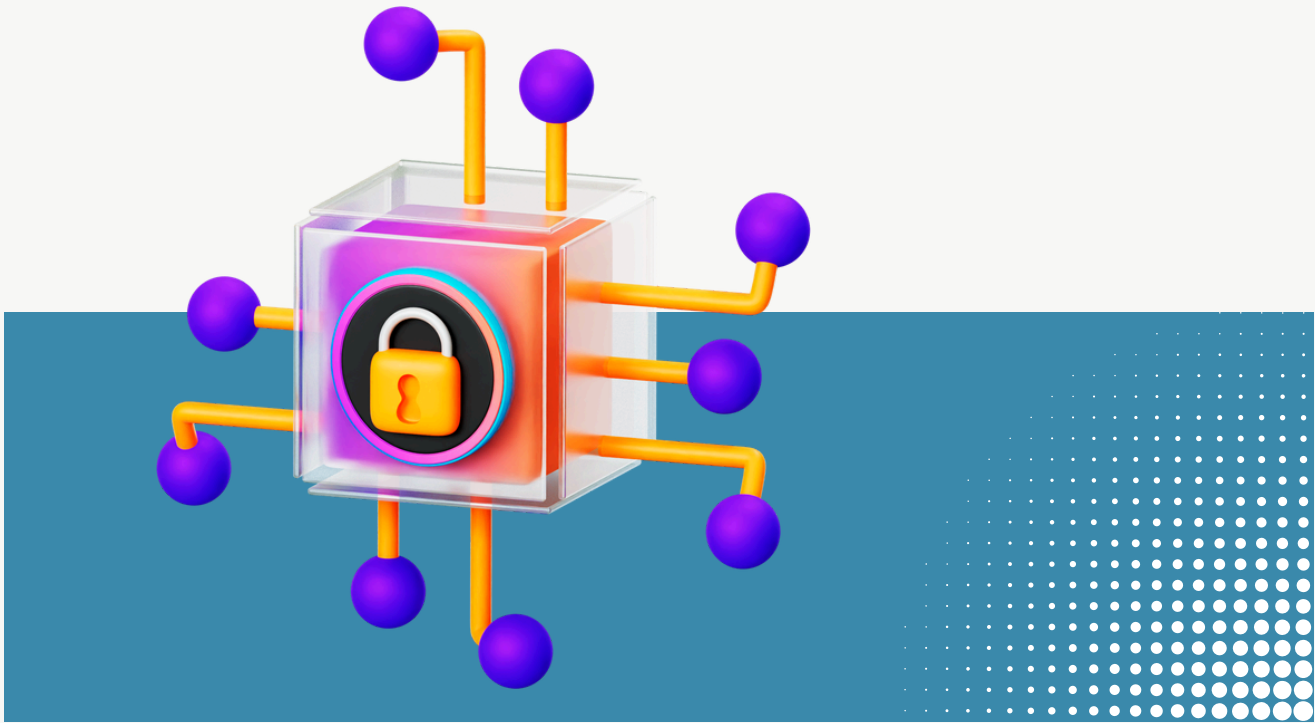
- *Individualization:* Personalized learning through adaptive platforms ensures that each student's educational journey is unique, addressing their specific strengths and areas for improvement.
 - *Efficiency:* By focusing on individual needs, adaptive learning can optimize the use of students' time, helping them progress at a pace that is neither too slow nor too fast.
-



Personalized Learning

- *Motivation and Engagement:* Tailoring content and challenges to a student's level of proficiency enhances engagement and motivation, as learners are more likely to find the material relevant and appropriately challenging.
- *Data-Driven Insights:* The AI algorithms generate valuable data on student performance and behavior, offering educators insights into areas that may need additional attention or intervention.

Personalized learning through adaptive platforms in the metaverse represents a shift from one size-fits-all education to a more dynamic and responsive model that aims to meet the diverse needs of individual learners in a virtual learning environment.



Blockchain Technology

The use of blockchain technology in education, particularly within the metaverse, introduces innovative solutions for secure and transparent credentialing processes. Here is an elaboration on the concept of using blockchain for digital credentials within the metaverse:

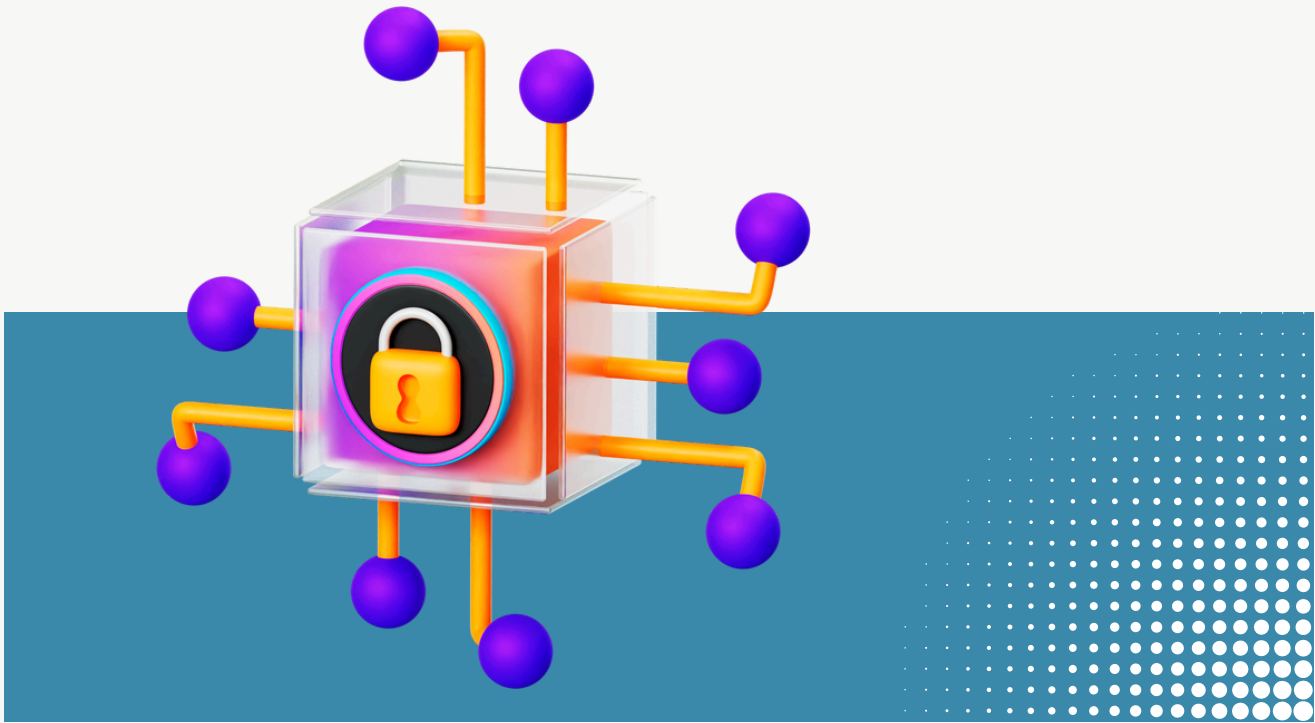
Digital Credentials and Blockchain in Education:

Definition:

- *Digital Credentials:* Digital credentials refer to electronic representations of an individual's achievements, qualifications, or skills. These can include certificates, diplomas, badges, or other forms of recognition for completing educational or training milestones.
- *Blockchain Technology:* Blockchain is a decentralized and distributed digital ledger that records transactions across a network of computers. It ensures transparency, security, and immutability of data through a chain of interconnected blocks.

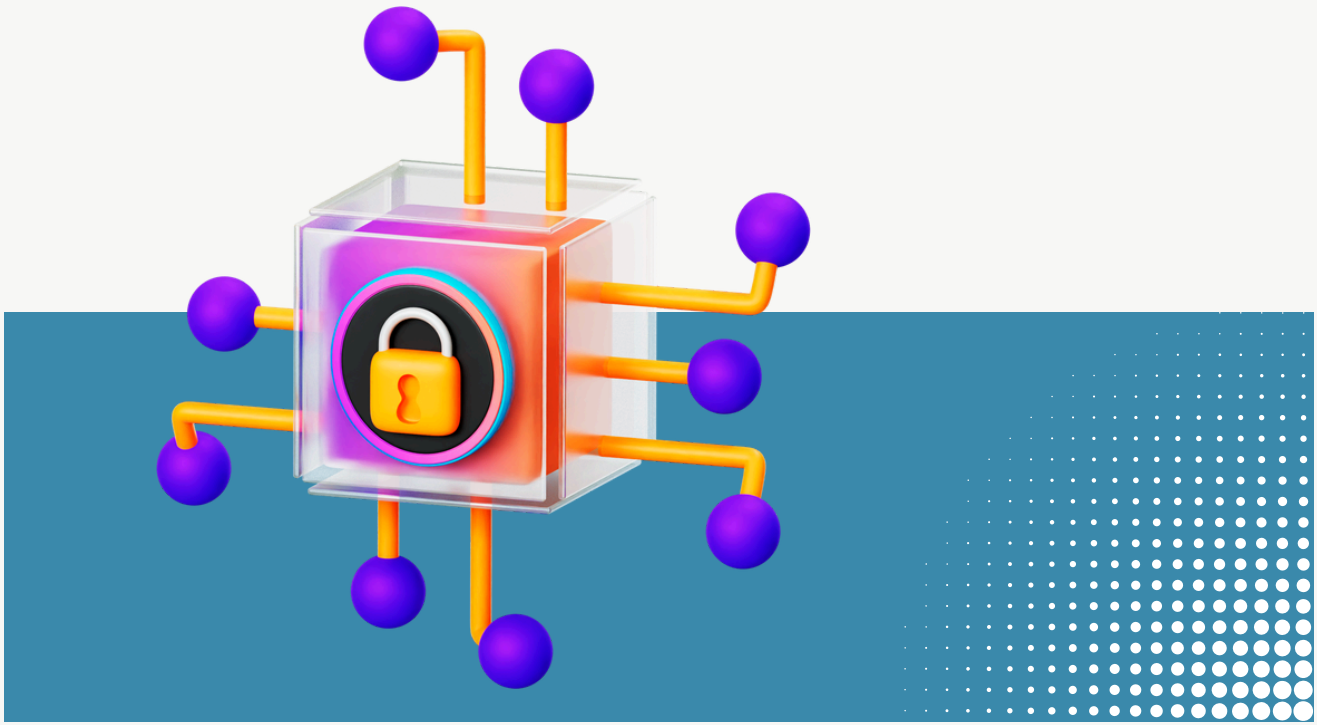
Utilizing Blockchain for Digital Credentials in the Metaverse:

- **Secure Issuance:** In the metaverse, educational institutions, training programs, or certification bodies can use blockchain technology to securely issue digital credentials. Each credential is cryptographically secured and linked to a unique identifier on the blockchain.
-



Blockchain Technology

- *Verification of Authenticity:* Blockchain enables a decentralized and tamper-proof system for verifying the authenticity of digital credentials. Employers, educational institutions, or any third party can independently verify the legitimacy of a credential without relying on a central authority.
 - *Ownership and Control:* Blockchain allows learners to have ownership and control over their digital credentials. Learners can store these credentials in their digital wallets within the metaverse, ensuring that they have easy access to and control over their achievements.
 - *Immutable Record:* Once a credential is recorded on the blockchain, it becomes an immutable and permanent record. This ensures that the information about a learner's achievements remains accurate and unaltered over time.
 - *Interoperability:* Blockchain can enhance the interoperability of digital credentials within the metaverse. Standards such as the Credential Transparency Description Language (CTDL) or Blockcerts facilitate the exchange and recognition of credentials across different platforms and institutions.
- Benefits:*
- *Enhanced Security:* Blockchain's decentralized and cryptographic nature enhances the security of digital credentials, reducing the risk of fraud or unauthorized alterations.
 - *Transparency:* *The transparent and decentralized nature of blockchain ensures that the entire credentialing process, from issuance to verification, is open and visible to relevant parties.*
-



Blockchain Technology

- *Reduced Credential Fraud:* Blockchain's immutability makes it extremely difficult for credentials to be forged or manipulated, reducing the risk of credential fraud.
- *Streamlined Verification Processes:* Using blockchain for credential verification streamlines the process, enabling quicker and more efficient verification of learners' achievements.

In summary, leveraging blockchain for digital credentials within the metaverse provides a secure, transparent, and decentralized system for recording, issuing, and verifying educational achievements. This approach not only enhances the integrity of credentials but also empowers learners with greater control over their educational records in the digital landscape of the metaverse.



Project-Based Learning (PBL)

Project-Based Learning (PBL) within the metaverse involves creating collaborative and immersive spaces where students can engage in hands-on projects, collaborate with peers, and showcase their work in a virtual environment. Here's an elaboration on the concept of using virtual project spaces in project-based learning.

Virtual Project Spaces in Project-Based Learning

Definition:

- *Project-Based Learning (PBL)*: PBL is an instructional approach that involves students working on a project or extended task that addresses real-world challenges, problems, or questions. It emphasizes active exploration, critical thinking, and collaboration.

- *Virtual Project Spaces*: These are collaborative online environments within the metaverse specifically designed for students to work on projects, share ideas, and present their work.

Features and Implementation:

- *Collaborative Environments*: Virtual project spaces provide a collaborative and interactive online environment where students can collaborate in real-time. They typically involve the use of avatars to represent students, creating a sense of presence within the virtual space.
 - *Project Development*: Students use the virtual project space to develop and work on their projects. This could involve brainstorming sessions, planning discussions, and the actual creation of project components.
-



Project-Based Learning (PBL)

- *Resource Sharing:* The metaverse allows for the integration of various media types, enabling students to share resources such as documents, images, videos, and links within the virtual environment.
- *Real-Time Communication:* Virtual project spaces often include features for realtime communication, such as chat functionalities or voice communication, allowing students to discuss ideas and provide feedback to each other.
- *Showcasing Work:* Once the projects are completed or at significant milestones, students can showcase their work within the virtual project space. This may involve presentations, demonstrations, or interactive displays.

- *Peer Collaboration:* The virtual nature of these spaces allows students to collaborate with peers regardless of geographical locations, fostering global collaboration and diverse perspectives.

Benefits:

- *Global Collaboration:* Virtual project spaces enable students to collaborate on projects with peers from different parts of the world, promoting cultural exchange and diverse perspectives.
 - *Immersive Learning:* The immersive nature of the metaverse enhances the learning experience by providing a dynamic and engaging environment for project work.
 - *Increased Accessibility:* Students can access virtual project spaces from anywhere with an internet connection, removing geographical constraints and allowing for flexible collaboration.
-



Project-Based Learning (PBL)

- *Enhanced Creativity:* The metaverse offers tools and features that can stimulate creativity, allowing students to experiment with ideas and express their projects in innovative ways.
- *Project Ownership:* Virtual project spaces give students a sense of ownership over their projects, as they actively contribute to the development, collaboration, and presentation aspects within the metaverse.

In summary, leveraging virtual project spaces in the metaverse for project-based learning provides a dynamic and collaborative environment where students can engage in meaningful, real-world projects, fostering creativity, teamwork, and the development of critical skills.



Global Collaboration

- Global collaboration within the metaverse involves creating opportunities for students from different parts of the world to connect, collaborate, and engage in cross-cultural exchanges. Here's an elaboration on the concept of fostering global collaboration through cross-cultural exchanges in the metaverse:

Cross-Cultural Exchanges in Global Collaboration:

Definition:

- *Global Collaboration:* Global collaboration in education involves connecting students, educators, and classrooms from diverse geographic locations to work together on projects, share ideas, and learn from one another.

- *Cross-Cultural Exchanges:* This refers to facilitating interactions and collaborations between individuals from different cultural backgrounds, promoting mutual understanding and appreciation of diverse perspectives.

Features and Implementations:

- *Virtual Meeting Spaces:* The metaverse provides virtual meeting spaces where students can gather, communicate, and collaborate in real-time. These spaces can simulate physical environments, creating a sense of presence even when participants are geographically distant.
- *Collaborative Projects:* Students engage in collaborative projects that involve teamwork, problem-solving, and the exchange of ideas. These projects can address global challenges, allowing students to apply their knowledge in real world contexts.



Global Collaboration

- *Language and Communication Tools:* Communication tools within the metaverse support multilingual interactions, breaking down language barriers. This allows students to communicate in their preferred languages, promoting inclusivity.
 - *Cultural Showcases:* Virtual spaces can be used to showcase and celebrate diverse cultures. Students may share aspects of their cultural heritage, traditions, and customs through multimedia presentations, exhibitions, or interactive displays.
 - *Real-Time Interaction:* The metaverse enables real-time interaction, fostering spontaneous and authentic communication between students. This immediate connection enhances the sense of collaboration and shared learning experiences.
 - *Educational Events:* Virtual events, such as lectures, seminars, or conferences, can be organized to bring together students and educators from different regions for shared learning experiences.
- Benefits:*
- *Broadened Perspectives:* Collaborating with peers from different cultural backgrounds exposes students to a variety of perspectives, fostering a more inclusive and global mindset.
 - *Cultural Competence:* Students develop cultural competence by engaging in cross-cultural exchanges, learning to appreciate and respect diverse ways of thinking and living.
 - *Language Skills Enhancement:* Interacting with students who speak different languages enhances language skills and encourages language learning in a practical context.
-



Global Collaboration

- *Global Problem Solving:* Collaborative projects addressing global challenges encourage students to think critically and find innovative solutions that consider different cultural contexts.
- *Building Global Networks:* Students establish connections with peers around the world, building a global network that may extend beyond the educational setting.

In summary, leveraging cross-cultural exchanges within the metaverse for global collaboration offers students the opportunity to engage with diverse perspectives, cultures, and ideas. It fosters a global mindset, enhances cultural competence, and prepares students for active participation in an interconnected and diverse world.



Digital Literacy and Ethics

Addressing digital literacy and ethics within the metaverse involves incorporating lessons on responsible use, digital citizenship, online etiquette, and ethical behavior. Here's an elaboration on teaching responsible use in the metaverse:

Teaching Responsible Use in Digital Literacy and Ethics

Definition:

- **Digital Literacy:** Digital literacy involves the ability to use and understand digital technologies effectively. It encompasses skills related to information access, evaluation, communication, and responsible use of technology.
- **Digital Ethics:** Digital ethics refers to the responsible and ethical use of technology, including considerations of privacy, security, and appropriate behaviour in online environments.

Key Components and Implementation

- **Digital Citizenship Education:** Educators within the metaverse can integrate digital citizenship education into the curriculum. This includes teaching students about their rights and responsibilities as digital citizens, emphasizing respect for others and ethical decision-making.
- **Online Etiquette:** Lessons on online etiquette, commonly known as "netiquette," are essential. Students learn how to communicate respectfully in virtual spaces, including email communication, online discussions, and collaborative platforms.
- **Privacy and Security Awareness:** Students are educated about the importance of protecting their personal information and respecting the privacy of others. This includes understanding privacy settings, avoiding cyberbullying, and recognizing the potential consequences of online actions.



Digital Literacy and Ethics

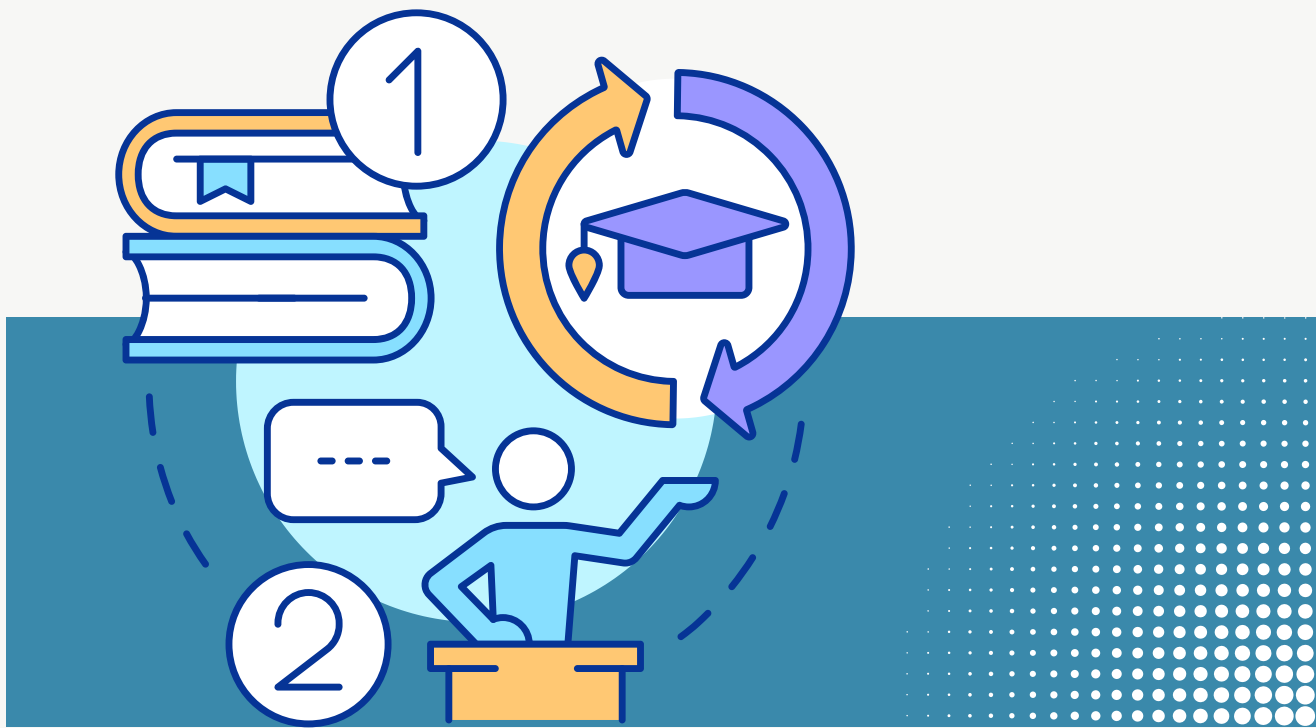
- *Critical Evaluation of Digital Content:* Digital literacy involves the ability to critically evaluate digital content for accuracy, credibility, and bias. Students learn to navigate information in the metaverse responsibly and make informed decisions about the content they engage with.
 - *Ethical Behaviour in Virtual Environments:* Lessons on ethical behaviour within the metaverse cover issues such as plagiarism, proper attribution of digital content, and the responsible use of technology for academic and personal purposes.
 - *Cybersecurity Awareness:* Understanding the basics of cybersecurity, including recognizing, and avoiding online threats, helps students protect themselves and their digital assets within the metaverse.
 - *Inclusive and Diverse Online Interactions:* Teaching students to embrace diversity and inclusion in virtual spaces is crucial. This includes promoting positive and respectful interactions with individuals from different backgrounds, cultures, and perspectives.
- Benefits:*
- *Empowered Digital Citizens:* Education on responsible use empowers students to navigate digital spaces with confidence, making informed decisions and contributing positively to online communities.
 - *Prevention of Cyberbullying:* Lessons on online etiquette and responsible behavior contribute to creating a positive and respectful online environment, reducing the risk of cyberbullying.
-



Digital Literacy and Ethics

- *Enhanced Digital Literacy Skills:* Students develop critical digital literacy skills, enabling them to evaluate information, discern reliable sources, and navigate the digital landscape effectively.
- *Preparedness for Future Technologies:* Teaching responsible use prepares students for future advancements in technology, ensuring they approach emerging technologies with ethical considerations in mind.

In summary, integrating lessons on responsible use, digital citizenship, and ethical behavior within the metaverse is essential for fostering a generation of digital citizens who navigate online spaces responsibly, ethically, and with a critical understanding of digital information.



Flipped Learning

The concept of flipped learning within the metaverse involves restructuring the traditional classroom model, emphasizing the utilization of digital tools to enhance students' engagement, understanding, and participation. Here's an elaboration on each component of flipped learning in the metaverse:

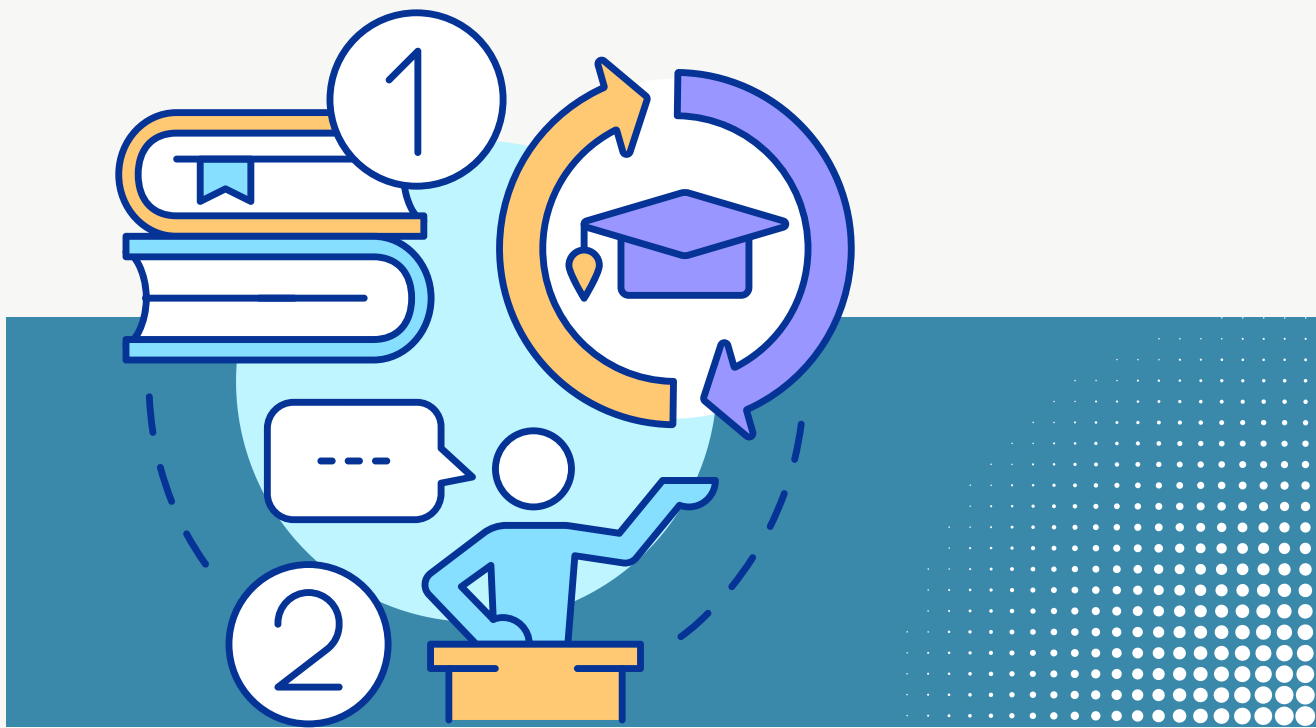
Pre-recorded Content

Definition: In the metaverse, educators create and share pre-recorded lectures, instructional videos, or multimedia content that students can access before the scheduled class time.

Implementation: These pre-recorded materials serve as the primary source for introducing new concepts, theories, or content. Educators leverage various multimedia formats to cater to diverse learning styles, making the learning experience more accessible and engaging.

Benefits:

- *Flexible Learning:* Students have the flexibility to access learning materials at their own pace and convenience, accommodating different learning rhythms.
 - *Revisit and Review:* Learners can revisit complex concepts or review content, reinforcing their understanding before engaging in class discussions.
 - *Resource Accessibility:* Pre-recorded content ensures consistent access to high quality instructional materials, overcoming time and geographical constraints.
-



Flipped Learning

Interactive Discussions:

Definition: Class time within the metaverse is dedicated to interactive discussions, problem solving activities, or collaborative projects, shifting the focus from content delivery to active student engagement.

Implementation: Educators facilitate discussions, encourage critical thinking, and guide students through application exercises. Virtual environments in the metaverse provide platforms for real-time interaction, allowing students to engage with peers and the instructor.

Benefits:

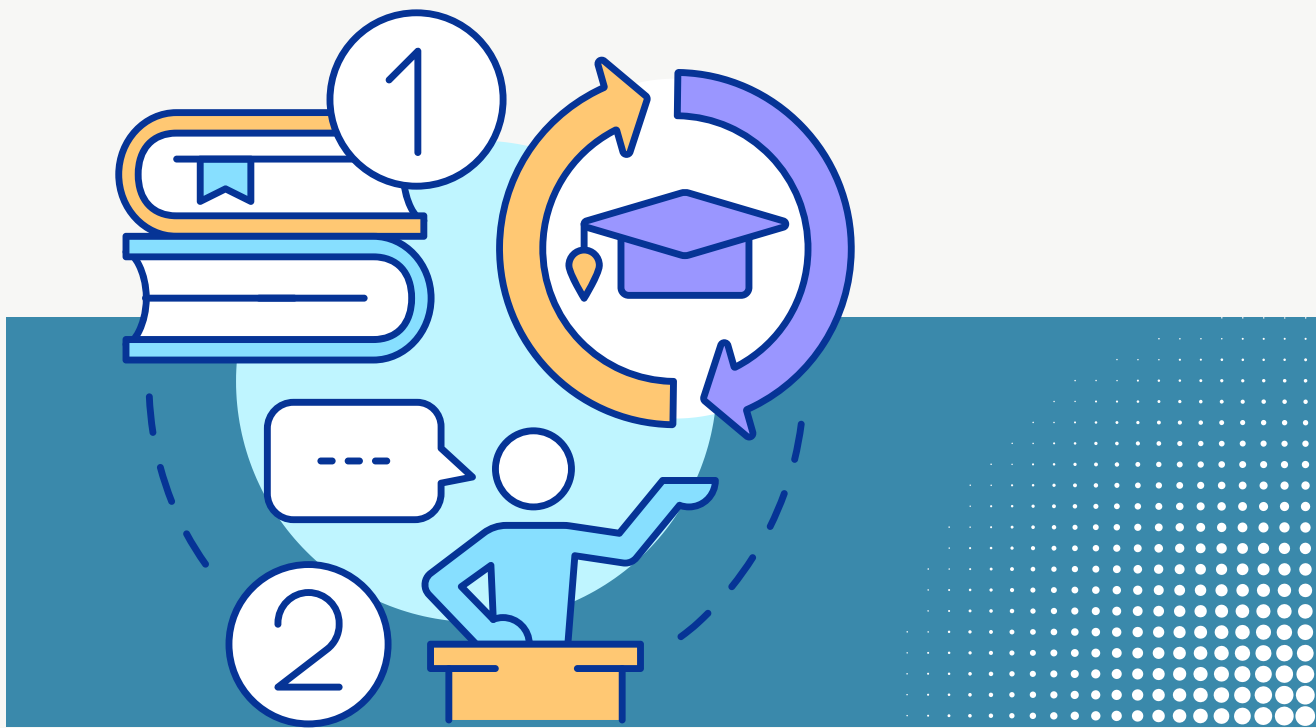
- *Active Participation:* Interactive discussions promote active participation, ensuring that students are actively involved in the learning process rather than passively receiving information.

- *Real-Time Clarifications:* Educators can address questions, provide clarifications, and offer immediate feedback, enhancing students' comprehension of complex topics.
- *Collaborative Learning:* The metaverse supports collaborative projects, fostering teamwork and communication skills among students.

Individualized Progress:

Definition: The metaverse facilitates tracking individual progress, allowing educators to monitor each student's performance and engagement with the pre-recorded material and class activities.

Implementation: Analytical tools and data metrics within the metaverse enable educators to assess individual progress, identifying areas of strength and weakness. This information informs personalized interventions or challenges based on students' understanding of the pre-recorded content.



Flipped Learning

Benefits:

- *Personalized Support:* Educators can provide targeted support to students who may need additional assistance, ensuring a personalized and adaptive learning experience.
- *Challenge Opportunities:* Students who demonstrate mastery early on can be provided with advanced challenges, catering to their individual pace and capabilities.
- *Data-Informed Teaching:* Individual progress data informs instructional decisions, enabling educators to adjust their teaching strategies based on students' needs and performance.

Summary: Flipped learning in the metaverse combines the advantages of self-paced learning with interactive and collaborative elements. Students have the flexibility to consume content independently, and class time is optimized for active engagement, discussion, and personalized support.

Advantages: The approach promotes a more engaging, student-centered, and personalized educational experience, aligning with the evolving needs and preferences of learners in a digital and interconnected world. The metaverse serves as a versatile platform that enhances the flipped learning model by providing immersive and interactive spaces for educational activities.

Lopez-Belmonte et al (2022, p 194) concludes in their research that both flipped learning and elearning “are relevant as an introduction to preparing students to acquire the skills and competences required by a training action in the metaverse”.

Conclusions

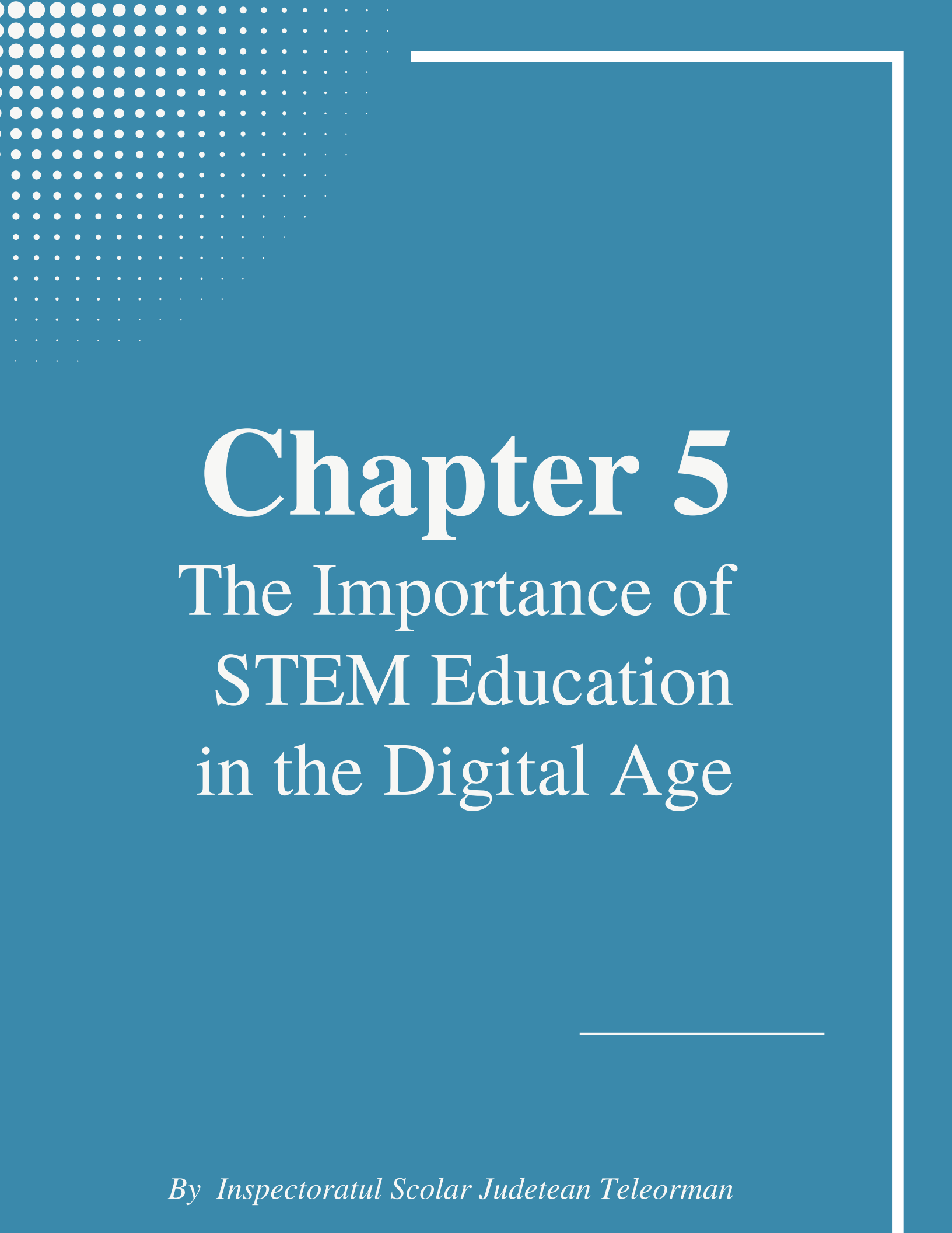
Navigating the metaverse with various pedagogical approaches presents both risks and benefits for education. On the downside, technological barriers may contribute to a digital divide, limiting access for some students. Security concerns, including data privacy and identity protection, pose potential risks. Additionally, uneven implementation of pedagogical approaches may result in varying learning experiences among students, potentially exacerbating learning inequalities. Overreliance on technology in the metaverse may become challenging in the event of technical issues or disruptions. Cross-cultural collaborations may encounter difficulties in understanding and respecting diverse cultural norms and values.

Mahir&Hanifah (2023) has presented a summary of the prior studies on the use of the metaverse within the education sector and exactly what they say is missing is what M-STEM is aiming to create and they explain it as follows: “As we continue to explore and develop the metaverse’s potential in education, there is a need for specific didactic methodologies competence training plans to support educators in creating and utilizing virtual classrooms effectively”.

However, the benefits can be substantial. Immersive experiences within the metaverse can significantly boost student engagement and motivation. The metaverse facilitates global collaboration, connecting students from around the world and fostering cultural exchange with diverse perspectives. Adaptive learning platforms within the metaverse offer personalized learning experiences, catering to individual student needs and enhancing the overall learning journey. Pedagogical approaches in the metaverse allow for practical, real-world application of knowledge through simulations and projects. Moreover, the metaverse provides flexibility and accessibility, accommodating diverse learning styles and overcoming geographical constraints.

In synergy, these pedagogical approaches leverage the metaverse as a versatile platform for transformative education. The metaverse becomes a catalyst for reimagining learning, offering educators and learners innovative tools to navigate a digitally interconnected world. This holistic approach prepares students for the future by fostering critical skills, global awareness, and a sense of responsibility in a technologically advanced and rapidly evolving educational landscape.

In navigating the metaverse with different pedagogical approaches, it is crucial to weigh these risks and benefits carefully to create an inclusive, engaging, and effective educational environment. Zhang (2023, p2057) concludes after having listed the basic attributes of the Metaverse that “overall, the Metaverse is a dynamic and evolving concept that is constantly changing and adapting to new technologies and user needs”. This is an important statement to have in mind while working with pedagogical approaches to the Metaverse since one of the basic attributes is “user-generated” which is a very important aspect that this project is about.



Chapter 5

The Importance of STEM Education in the Digital Age

By Inspectoratul Scolar Judetean Teleorman

Introduction



Modern societies, especially those in the European Union, have begun to focus on sustainability, highlighting the challenge of climate change. The energy transition requires citizens to have green and entrepreneurial skills, which are developed in combination with basic skills and, of course, soft skills. In this scenario, digital skills are also part of the skills that European citizens should have in their daily lives. This combination of skills is supported by European policies, both through sectoral and cross-cutting policies, such as the European Green Pact, the EU Skills Agenda and A compass for the digital dimension.

At the ALL DIGITAL Summit, which took place on 14 October 2021, Anusca Ferrari, EU Policy Officer, in her speech at the opening of the event, highlighted the objectives and initiatives of the European Union: "We have established that STEM is a priority for higher education cooperation projects in the Erasmus+ 2021 work programme. [...] Only 1 in 5 young people in Europe graduate from STEM tertiary education, and in European Union we have less than 2 million STEM graduates annually. Even if we try to promote an inclusive approach to STEM education, we know that, in fact, women are strongly under-represented in the sector: 1 in 3 STEM graduates is female. The situation is even worse when we look at ICT studies, where only 1 in 5 ICT graduates is a woman."

Consequently, in the rapidly evolving landscape of the 21st century, the integration of Science, Technology, Engineering, and Mathematics (STEM) education has become imperative for preparing students to thrive in the digital world. As technological advancements continue to shape our society, STEM education serves as a catalyst for innovation and progress. This chapter explores the changes that have appeared in education as a result of the 4th Industrial Revolution, the significance of STEM education in the digital age, its impact on student learning and the skills they will acquire, as well as the evolving role of educators in fostering a generation of digitally literate individuals.

Education Requirements in the 21st century

In the last three centuries, mankind has witnessed four Industrial Revolutions which have caused gigantic leaps in industrial development. The impact they have had on human civilization and the way we live our lives is massive. The first industrial revolution took place in the 18th century, when the steam engine was introduced, completely transforming the transportation and manufacturing sectors. The 19th century was clearly marked by the introduction of electricity and mass production, which is known as the second industrial revolution. The third one, attributed to the 20th century, brought with it semiconductors, computing and the use of internet, thus connecting people all over the world, but, at the same time, resulting in the globalization of communication and trade.

The current era, referred to as the 4th industrial revolution, is characterised by unprecedented invention and rapidly emerging technological breakthroughs, which has led to a such a fast pace of digital transformations and fusion of technologies that the boundaries between the physical, digital and biological spheres are no longer clear, but, on the contrary, they transcend and blur.

We have been the witnesses of the ‘unthinkable’ becoming a reality, when artificial intelligence, 3D printing, autonomous vehicles, nanotechnology or sophisticated robots have become part of our daily lives. All these innovations, collectively, have done nothing else but emphasize the importance of STEM and the role of STEM competences in contributing to economic growth, productivity and meeting future demand.

Given the above-mentioned transformations, education could not have remained “untouched” or “resistant” to change. Since the first industrial revolution, schools have taken on the mission to prepare students for the workplace, equipping students with basic skills, by providing a certain body of information, considered not only important but also viewed as norm by the majority.

Nowadays, however, the expectations are shifting – the students educated in today’s schools are expected to function, in a not very remote future, as adults belonging to a rapidly changing world, work under conditions characterised by uncertainty; moreover, these future adults will have to deal with a continuously increasing amount of information, become familiar, or even master, new technologies; these new mediums will facilitate their work, collaboration and communication.

Education Requirements in the 21st century - I

Knowledge and knowledge-oriented practices are assuming greater importance than ever before. More than that, tomorrow's adults will compete over jobs with millions of people from all over the world, as a consequence of digitalization and globalization. Therefore, it comes as no surprise that educators, parents, business leaders and policy-makers express their concerns that education institutions, too often, fail to prepare students for the demands of the 21st century.

This is the reason why many states are attempting to change their schools and adapt them to the 21st century demands, by introducing or, in some cases, even imposing various reforms in education. The problem is that these changes and reform processes engage teachers' knowledge and commitment; actually, it is paramount that teachers exercise their own professional judgement in the change process, which has proved to be not at all easy.

The new skills in an era of change

Today's society expects schools to foster knowledge creation and life-long learning skills. Graduates of 21st century schools must be proficient in the basic academic skills areas of reading, writing and elementary mathematics, but, at the same time, they must be prepared to learn new things, collaborate in identifying solutions to various problems and produce innovation in areas that currently may not even exist.

Scholars have come up with many terms, trying to describe and articulate this range of skills (such as the 21st century skills, life-long learning skills or 21st century competences). They have also made attempts to define the competences, abilities and dispositions people need in order to be successful in tomorrow's world.

One such classification refers to four main domains: (meta)cognitive, inter-personal, intrapersonal and technological. Skills in the cognitive domain span the learner's ability to construct meaningful and in-depth knowledge, as well as to apply it creatively in new situations and contexts. Metacognitive awareness and self-directed learning were ranked as important cognitive attributes. The inter-personal domain deals with a person's ability to engage with others, such as through teamwork, leadership and cooperation, whereas the intra-personal domain concerns one's response to problems and challenges, such as intellectual openness, self-regulation and managing emotions. Finally, the technological domain relates to one being literate with respect to information and communication technology (ICTs).

Technology does play a crucial role in teaching today. Even in schools with low or limited use of it, metaphorically, technology has entered "through the back door". No matter where one teaches, when giving homework assignments, educators need to consider that students may use the internet (even searching for ready-made essays or solutions to problems), which will definitely diminish the intellectual efforts required.

That is why, the voices from media and academics are split between those with pessimistic versus optimistic opinions about the effects of ICTs on young people. Those in favour of introducing technology in classrooms see it as an opportunity for "self-expression, sociability, community engagement, creativity and new literacies", whereas pessimists consider "social networking as time-wasting and use of other ICTs in schooling as taking shortcuts, cheating, that may have a negative impact on the development of study skills". Whether we belong to the category of optimists or to those who fear the dangers it might bring along, we must all acknowledge the transformational role of technology in both students' and teachers' lives.

The importance of STEM skills in ensuring a sustainable future

The United Nations' 2030 Agenda for Sustainable Development, titled "Transforming our World", has established 17 Sustainable Development Goals, whose fulfilment will have as result a diminishing of poverty and food shortage; they will also help to deal with issues such as climate change, the protection of the planet and will ensure that all individuals enjoy peace, prosperity and a quality of life for all.

Education, and particularly STEM education, plays a crucial role in achieving these goals. Here are the particular areas where STEM education is expected to elaborate and provide innovative solutions that will solve global issues: Zero Hunger (which was established as Sustainable Development Goal no.2); Good Health and Well-Being (Sustainable Development Goal no.3); Clean Water and Sanitation (Sustainable Development Goal no. 6); Affordable and Clean Energy (Sustainable Development Goal no. 7); Decent Work and Economic Growth (Sustainable Development Goal no. 8); Industry, Innovation and Infrastructure (Sustainable Development Goal no. 9); Sustainable Cities and Communities (Sustainable Development Goal no. 11) Responsible Consumption and Production (Sustainable Development Goal no. 12); Climate Action (Sustainable Development Goals no. 13).

The question therefore arises: how can STEM education bring its crucial contribution to achieving all these goals. To provide the best answer and examples, it is necessary to mention the different conceptions of what STEM means in practice; the perspective from which it is viewed within the education system appears to be the most important defining factor.

There are many people who think of STEM as four separate subjects (Science, Technology, Engineering and Mathematics). Others consider STEM to be an integration of two, three or all four disciplines. It is true that each of these disciplines has its own history, philosophy and principles, as well as its own knowledge, skills and functions; nonetheless, in the last decades, researchers considered that the four disciplines should be brought together, as STEM; they support their claim with the main argument that science and mathematics are generally considered to form the basis of applied science, which includes technology and engineering.

The entity now known as STEM, first proposed in the 1990s by the US National Science Foundation, addressed a rising concern that many students would not be able to keep up with the changes brought about by the digital revolution, and might even be left behind, in the globally competitive marketplace. An increasing demand for STEM related skills and competencies was therefore felt deeply.

The importance of STEM skills in ensuring a sustainable future - I

How can we define STEM competence? Can we refer to it as a mere set of fixed skills or is it rather a developmental capacity? According to specialists, STEM competence defines an individual's ability to apply STEM knowledge, skills and attitude appropriately in his or her everyday life, workplace or educational context. It includes both the 'know-what' (the knowledge, attitudes and values associated with the four disciplines) and the 'know-how' (which refers to the skills that are needed to apply that knowledge, taking account ethical attitudes and values in order to act appropriately and effectively in a given context).

After we have pointed out the complex contents of STEM competence (as comprising knowledge, skills, attitudes, and values), further on, we would like to present, in more detail, the main skills which are required in carrying out STEM-related tasks. They include cognitive, manipulative, technological and collaboration and communication skills.

Cognitive skills - the range of cognitive skills needed include information management and processing, (identifying, collecting, processing and using relevant data to make decisions) critical, creative and analytical thinking, problem solving skills, scientific investigation, creativity and computational thinking. Today, enormous amounts of information are gathered and used in all domains of life. Information processing skills are thus required to find, collate, organise and select valid information for specific tasks; this is needed in order to generate, understand, interpret and analyse empirical data, but at the same time, to test its authenticity, validity and reliability.

Another important skill developed through STEM education is that of problem solving: the process is a complex one, which consists of identifying and breaking down complicated problems into parts or components, analysing data, developing solutions, evaluating options, and implementing solutions. This skill turns out to be useful in scientific investigation too, which scientists use to explore and find answers to existing phenomena in the world around them.

The effective use of Information and Communications Technology (ICT) skills and connectivity are important to the advancement of the STEM fields. Basic ICT skills include the technical ability to use a computer, tablet, or mobile phone, send emails, browse the internet, make a video call and use computer software to search for information and create presentations. Coding is another essential skill which involves programming sets of instructions or algorithms to enable computers or ICT gadgets to perform certain tasks.

The importance of STEM skills in ensuring a sustainable future - II

Design thinking has become a necessity in this age of great innovation, invention and creativity and it involves a structured framework of creative strategies and processes to develop products and solutions, not restricted to rigid techniques or rules. Design thinking is based on information gathering, creative brainstorming, trial and error, review, redesign, testing and implementation that can be effectively applied to STEM learning and STEM careers.

Manipulative skills refer to the correct and safe use and handling of scientific and/or technical equipment, apparatus, specimens, and substances which may be specific to a particular career or vocation, among which we can mention electricians, cardiovascular technologists, aircraft mechanics or mechatronics engineers.

When referring to **vocational or technological skills**, we mainly associate them to the training some countries provide at secondary schools which assist students to make more informed decisions about their future careers. However, because vocational skill-sets constantly and rapidly change, schools often find it a challenge to keep up to date with innovations.

Effectively **collaborative and communication skills** do not always occur naturally and need to be explicitly developed; effective teamwork is required since most tasks are complex and interrelated and cannot be achieved by a single person's effort. There are multiple benefits of effective collaboration, among which the equal chance every team member must participate and communicate ideas, as well as assuming and sharing responsibility.

Challenges of STEM education in the digital era

For generating and implementing a pedagogical transformative change, teachers are essential. Well-educated and highly motivated teachers are at the core of successful educational systems. Barber and Mourshed, two highly respected researchers, pointed out that the quality of an education system cannot exceed the quality of its teachers; they also stressed the fact that the only way to improve outcomes is to improve instruction and achieving universally high outcomes is only possible by putting in place mechanisms to ensure that schools deliver high quality instruction to every child. (Barber, M., & Mourshed, M. (2007). *How the World's Best-Performing School Systems Come out on Top*. The Free Press. p. 40).

Such claims put enormous pressure on teachers, who need to adapt their pedagogy to the 21st century learning, to prepare students for continuous and self-regulated life-long learning, to help them become able and willing to collaborate with others, and well-informed and well-networked citizens. Teachers too need to embrace life-long learning skills and dispositions. Many of these educators may not have received adequate training in using technology in the classroom, and professional development opportunities are essential. Providing ongoing support and training for teachers helps them stay abreast of technological advancements and effectively incorporate digital tools into their teaching methodologies.

Another challenge schools and educational institutions often face is related to the technical infrastructure needed for seamless integration of technology. The use of digital resources in STEM classrooms can be impeded by outdated hardware, limited bandwidth and unreliable internet connectivity. It is therefore crucial that schools invest in robust technical infrastructure in order to ensure a smooth technological integration. It must also be mentioned that, sometimes, teachers struggle to adapt existing STEM curricula to incorporate the latest technological tools and advancements, since the rapid evolution of technology can outpace the development of educational curricula.

Conclusions

Why is STEM important? The global economy is changing. Current jobs are disappearing due to automation and new jobs are emerging every day as a result of technological advances. The continual advances in technology are changing the way students learn, connect and interact every day. Skills developed by students through STEM provide them with the foundation to succeed at school and beyond. Moreover, employer demand for STEM qualifications and skills is high, and will continue to increase in the future. Currently, 75 per cent of jobs in the fastest growing industries require workers with STEM skills.

In the digital era, where technology is at the forefront of nearly every industry, STEM education equips students with the skills necessary for success in the workforce. Proficiency in coding, data analysis, and technology literacy becomes increasingly important, and STEM education ensures that students are well-prepared for the demands of the modern workplace. Therefore, it is no surprise that nations with a strong focus on STEM education tend to be more competitive in the global arena. A well-educated STEM workforce contributes to economic growth, technological advancements, and innovation.

Moreover, STEM education encourages an interdisciplinary approach, breaking down traditional barriers between subjects. Students learn to integrate knowledge from various disciplines, mirroring the interconnected nature of real-world challenges. This interdisciplinary learning not only enhances the depth of understanding but also prepares students for the diverse and dynamic nature of modern careers.

Finally, STEM fields have historically faced issues of underrepresentation, particularly concerning gender and minority groups. STEM education initiatives strive to address these disparities by promoting inclusivity and diversity. Encouraging students from all backgrounds to engage in STEM subjects ensures a broader range of perspectives and ideas, fostering a more inclusive and equitable society.



Chapter 6

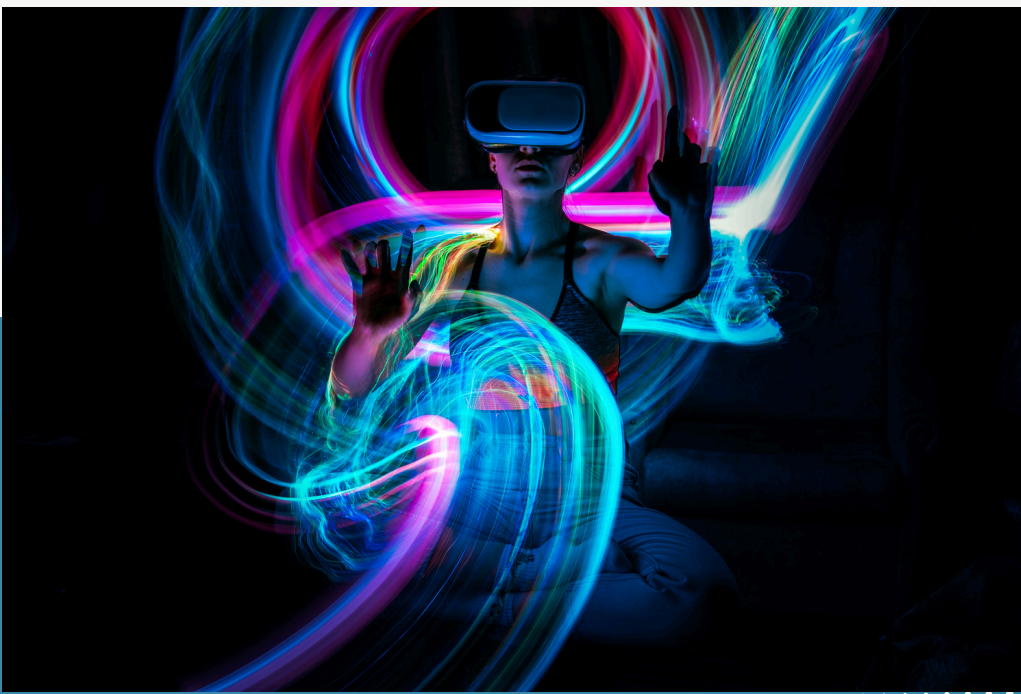
Introduction to the
concept of
metaverse and its
potential for
learning

By Lycée Clément Ader

Introduction

We had already experienced the promise of a technological revolution with the emergence of the Internet, which had nourished many hopes and libertarian dreams. Reality and pragmatism prevailed in the end, as it was the merchant platforms, the social networks and the majors who ended up imposing their economic model, fostering user dependency by developing strategies of capture. Digital magic words are regularly appearing cloud, big data, deep learning, AI. Metaverse is one of the latter words, popularized by Facebook in 2021 when Marc Zuckerberg announced that the Facebook group would henceforth be called Meta. The metaverse has not yet been born, but Facebook's creators and multinationals are already bending over backwards to make it a major part of their business strategy. Confinement at Covid 19 also highlighted the need for teachers and students to have access to reliable, easy-to-use digital tools for synchronous or asynchronous remote working. For many companies and governments, metaverse could be a solution. In this way, metaverse can be seen as a tool for learning and criticism, rather than yet another tool of fascination designed to sustain ever more delirious and toxic consumption.

The aim of this chapter is to introduce you to the metaverse and consider the added value it could bring to teaching.

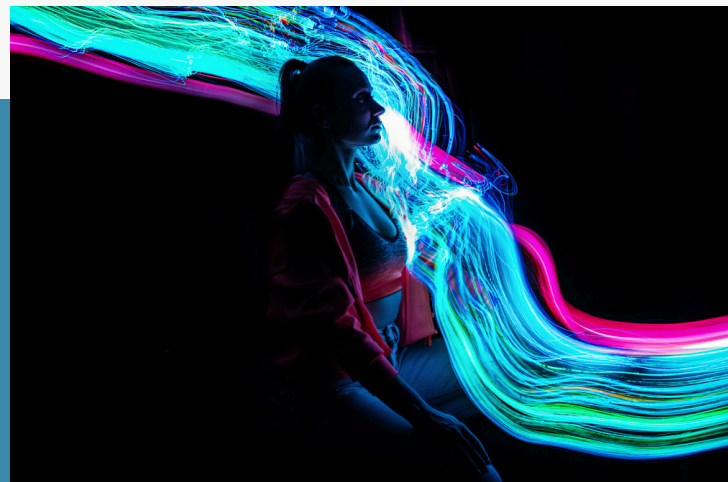


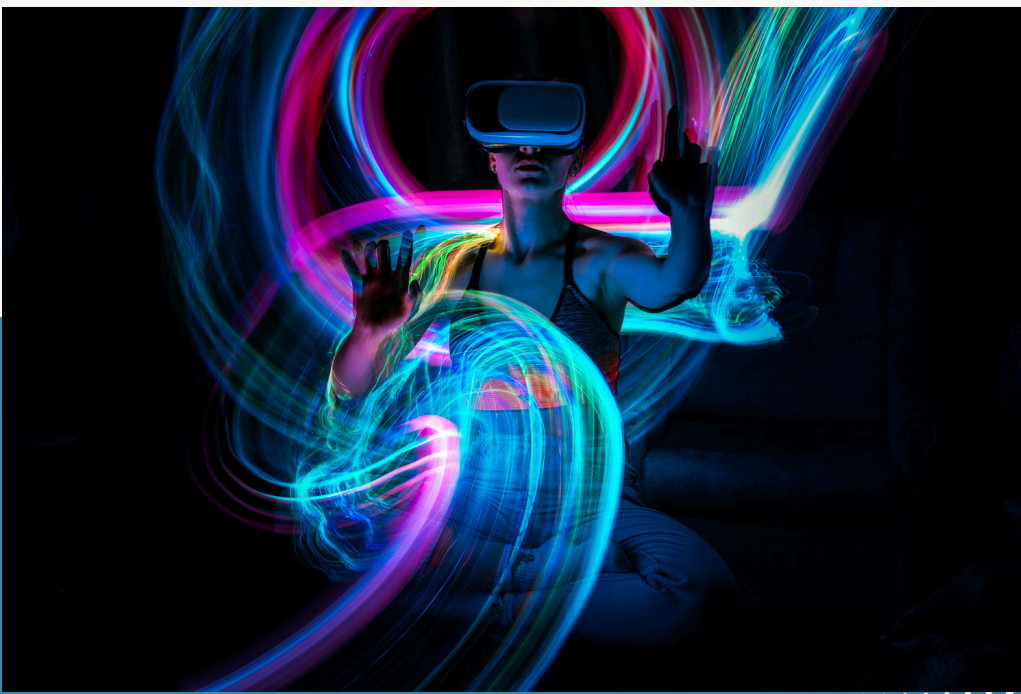
What is Metaverse? _____



What does metaverse mean? The expression has a wide range of meanings and seems to change according to the use and technical solutions it implies, and the platforms that implement it. So, not one metaverse, but many metaverse? A clarification is in order. Let's begin by trying to understand the origin of this term, to better determine what defines metaverse.

The term "metaverse" was first used in Neal Stephenson's 1992 novel "Snow Crash". In this science-fiction story, the characters evolve within an immersive virtual reality that is perceived as a kind of evolution of the Internet. From this point of view, the metaverse refers to a virtual parallel universe in which real people in the form of avatars can interact with each other in a digital and virtual space.





What is Metaverse?

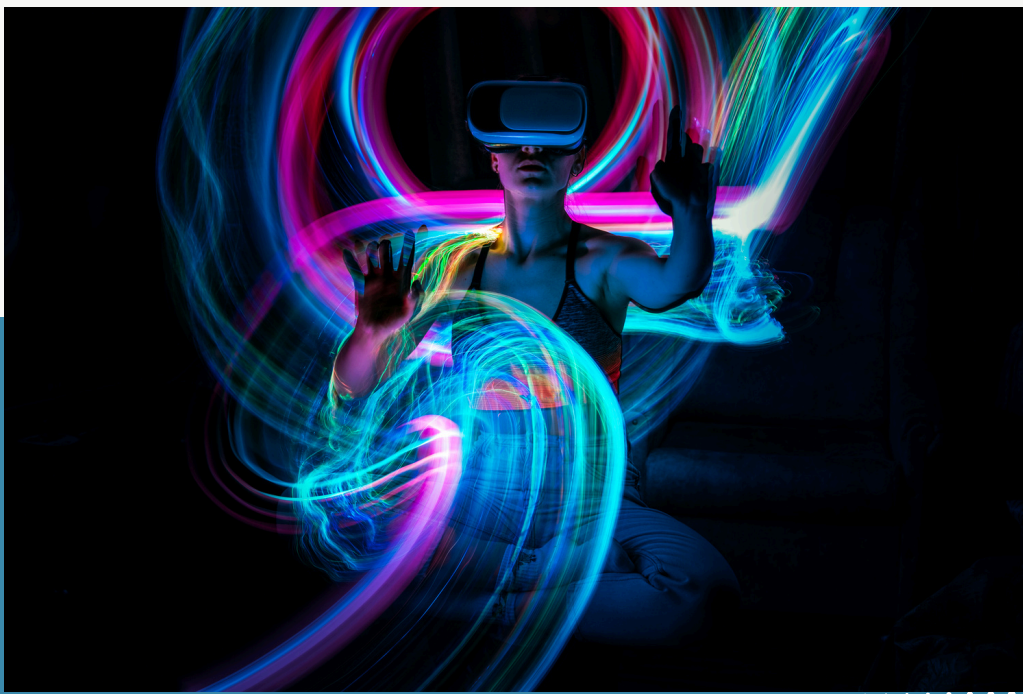
Instead of simply consuming content passively, metaverse users can take an active part in a constantly evolving environment. It's the concept of interaction that comes to the fore, in contrast to the passive relationship implied by the Internet as we know it. We will therefore retain the idea of interaction as constitutive of the metaverse.

Etymologically, the word is formed from "meta", meaning "beyond" in ancient Greek, and "verse", evoking the universe (beyond the universe). Etymologically, the word implies that the metaverse offers something more than what the real allows. This acceptance is essential, as it implies that the metaverse is not a duplication of what the real allows, but that it adds value and something more. From this point of view, it is important to try and envisage more precisely what the metaverse would bring to a classic pedagogical situation, and to list these possibilities.

In fact, metaverse were first developed in the field of video games in the 1990s. The creation of multiplayer environments, fostering the first virtual interactions, played a decisive role in its spread. Since then, many digital players have been working to enrich these interactions by incorporating new technologies such as virtual reality, augmented reality, satellite imagery and digital creation.

What are the invariants of the metaverse?

- 3D environment, but not necessarily with a VR headset
- Persistent: the metaverse continues to evolve even if the person is no longer in it.
- Avatar: creation of a character that represents us in the metaverse
- Being able to meet up with others at a distance (virtual presence: self-presence (avatar), spatial presence (credible environment) co-presence (other avatars are other people) Clément Merville, 'Ecole Polytechnique executive education



How is the Metaverse perceived?

Based on this Ifop1 survey of a sample of 1,022 people. We can see that a double divide persists in the representations of those surveyed, maintaining the risk of a digital divide that is a factor of imbalance and inequality.

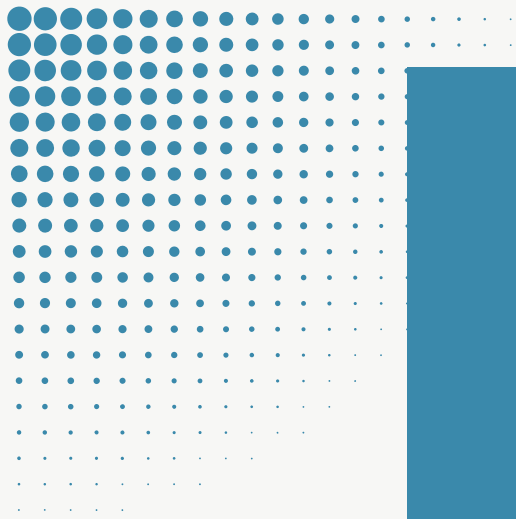
In fact, only 35% of those questioned said they knew what the metaverse stood for, and only 14% were able to be precise. What the survey reveals is a generational divide. Younger people have a better understanding of metaverse, with 42% of 18-24 year-olds knowing what metaverse are, compared to just 28% of those aged 65 and over.

But it's above all on a social level that the divide seems worrying, with 59% of higher education graduates aware of metaverse, compared with just 27% of people with no qualifications. A double generational and social divide that can be seen

in the representations.

Finally, a major prejudice that can distort representations and act as a brake on the development of the metaverse in the world of education. Those surveyed do not see the possibilities of developing the metaverse other than as a form of play dedicated to games. Indeed, 21% of those questioned thought that the metaverse was useless. This can be explained in part by the very origins of metaverse development mentioned in Part 1.

It is to work against these representations that we offer you this guide, in the hope of better assessing the pedagogical potential of this tool, which is still under development.

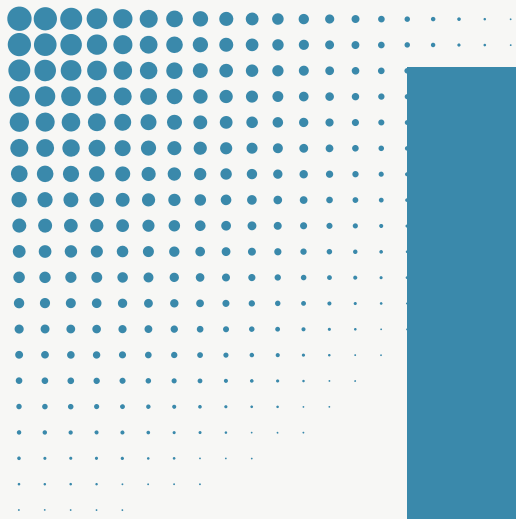


Common Misconceptions

01

Immersive technologies will replace trainers and teachers

Certain fears linked to technological innovation fuel persistent fantasies that science fiction feeds on. The fear of inhumanity and of machines remains a founding axis of science fiction literature. Let's not confuse the issue: the metaverse will remain a tool, a showcase, a container, while the teacher thinks in terms of progression according to the level of his pupils. The metaverse can never replace pedagogical reflection based on interaction with students. Students need to build a special relationship with their teacher. This affective, critical, and pedagogical dimension cannot be digitized. The metaverse is an empty shell; it's up to the teacher to decide on its content.



Common Misconceptions

02

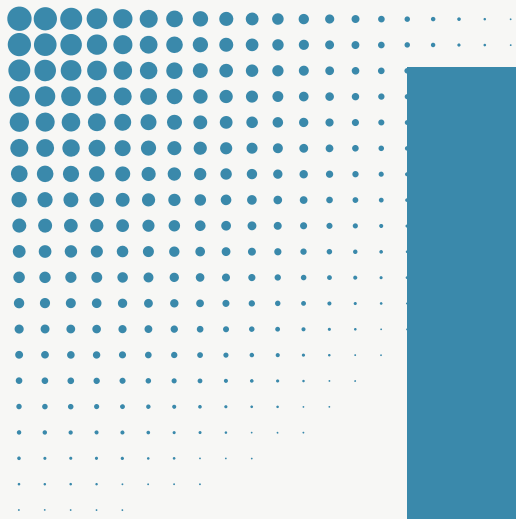
Immersive technologies make people sick or cause discomfort

The charter of recommendations for VR (2019) and the 2021 report by the Agence nationale sécurité sanitaire alimentaire have examined the negative effects induced by VR. According to these studies, they depend on three factors that are not solely hardware-related

Users' physiological predispositions:

- The hardware used, and older-generation devices with unsuitable display rates. Newer generation devices have corrected this dysfunction.
- The nature and design of experiments

Company trials show that VR headset use should not exceed 30 minutes (Clément Merville, Ecole Polytechnique Executive Education, 2023).



Common Misconceptions

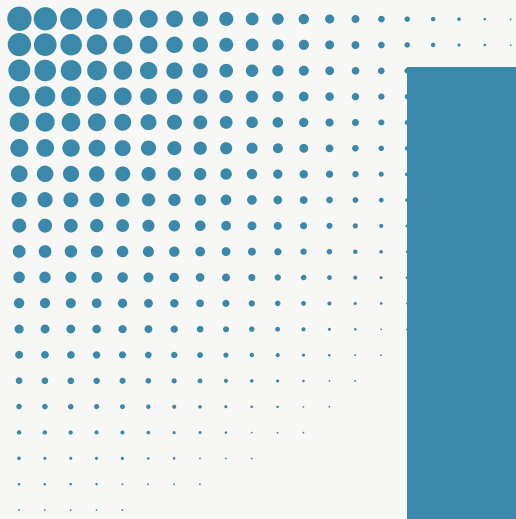
03

Immersive technologies are not yet sufficiently developed

More and more companies and universities are using immersive technologies in fields as varied as recruitment, meetings, and apprenticeships: laboratory safety at university, learning technical gestures in medicine or business to guarantee the safety of those involved.

Non-Fungible Token (NFT) which are unique digital assets transacted in cryptocurrencies and exchanged using a blockchain protocol. A non-fungible token is often presented as a title deed, recorded in a public, decentralized digital register. The art market, but also land sales, are seizing on NFTs. So, once you've bought an NFT work of art, you can invite others to visit it in VR. This is another aspect of immersive technologies.

Many fields of application for immersive technologies have been identified: online conferences and meetings, mobile video games and social networks (Pokemon Go), online shopping, cultural experiences, digital twins, pornography, ubiquitous computing, training and learning, healthcare, administration and online services (Theshiftproject, 2023).



Common Misconceptions

04

Immersive technologies are too expensive, especially for the climate

Reducing global warming caused by the increasing concentration of greenhouse gases in the atmosphere is a priority for all countries. Regarding digital technology, the 6th IPCC report shows the ambivalence of digital technology in limiting our carbon footprint:

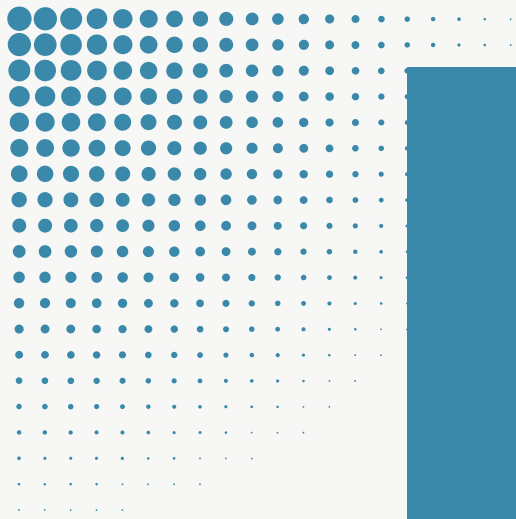
"Digital technologies have significant potential to contribute to decarbonization due to their ability to increase energy and material efficiency, make transport and building systems less wasteful, and improve access to services for consumers and citizens."

but with limited associated evidence:

"The digitization of the economy is often cited as offering new mitigation opportunities, but knowledge and evidence are still limited - such as understanding the role of smart apps and the potentials and influence of disruptive demand and supply-side technologies on GHG (greenhouse gas) emissions."

Clément Merville (2023) believes that a metaverse design based on the replacement of certain GHG-emitting actions will help reduce overall carbon footprint: "Finally, this metaverse produces ten times less greenhouse gases than conventional videoconferencing solutions. The reason is quite simple: all the images required to create the environments in the metaverse are calculated locally, directly on the user's machine. The only information passing through the network - the heart of the production of greenhouse gas emissions - is thus minimized. This would give this emerging metaverse other characteristics than advertising or NFTs."

For Carole Davies-Filleur (2023), "we need to take into account the consequences of these digital transformations very early on in the production of these new uses. And to do this, we need to ask ourselves the question of the environmental, social and ethical balance of the user experience we want to put in place, in the face of their remunerative value, in the face of their financial profitability."

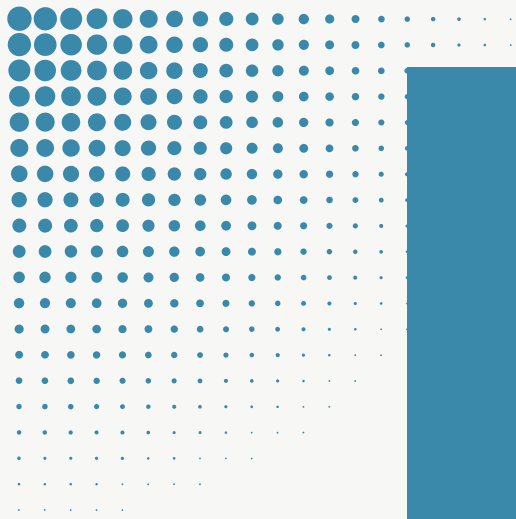


Common Misconceptions

05

Immersive technologies are reserved for young people and video gamers

According to Raphaël Granier de Cassagnac (Chair of Video Games at Ecole Polytechnique, 2023), metaverse have long existed for gamers. Many games are already played by several players, and more and more gamers are abandoning single-player games. However, metaverse can provide real added value in the context of specific and dangerous training for the experimenter (risky handling in a nuclear power plant) or for the patient (surgical procedure). Virtual reality allows you to train as many times as necessary before performing the action. So, you don't have to be a gamer or a young person to use the headset and joysticks to repeat the necessary gestures. For a VR activity to be engaging for the user, the avatar must be as realistic as possible, and interactions between individuals must be fluid, unlike Carrefour's recruitment meeting in May 2022, whose graphic qualities are reminiscent of 80s video games.



Common Misconceptions

06

You need a headset - not everyone has one!

The VR headset is the tool for a successful immersive experience. It's a must-have piece of equipment for the classroom. Except for the Apple vision pro headset, which costs 4,000 euros, it's possible to get a quality headset for around 400 euros. The investment is therefore affordable, bearing in mind that you don't need 35 headsets. Buying 5 headsets for a class is quite sufficient.

However, even if the manufacturers' aim is to have all connected devices (computer, tablet, smartphone) present with the VR headset, we have to admit that all these devices are "stacking up" in schools and in private life. The tablet hasn't replaced the computer, the smartphone hasn't replaced the tablet... All these devices require rare metals to manufacture, and their grey energy is significant. The massive development of VR headsets therefore poses a real environmental and energy problem.

What added value for learning?

Remember that in the introduction to this chapter, we tried to define what the metaverse could be. Immersion and interaction were two criteria that seemed relevant to us. If we're concerned with education, immersion and interaction are tools that can enrich our pedagogical practices. What are the conditions for successful learning?

Defined empirically by pedagogues since the 19th century, then validated by neuroscience, the 4 pillars of learning are: attention, active engagement, feedback, and consolidation.

Attention and concentration

Attention is a learner's ability to channel his or her attention to the task in hand, to give less room to unnecessary stimuli to focus on the task in hand. The learner must therefore learn to select and not be invaded by external stimuli (thoughts, movements in the courtyard and in the classroom, etc.) that would limit his or her concentration on the task in hand (see J-L LACHAUX, 2018).

Immersive experience can therefore be a tool for enhancing learners' attention in the learning process. Indeed, the direct consequence of donning a virtual reality headset is that the user is plunged into a fully-fledged universe that takes the place of the real world. The latter disappears, along with all its distractions. This makes it easier for learners to detach themselves from external stimuli that disrupt their attention.

Scientific studies seek to assess the impact of immersive technologies on learner concentration. A study of elementary school pupils in Taiwan shows a positive impact of VR use on pupils' concentration compared with computers. (Guide Immersive learning, p35)

Immersive learning is therefore a new possibility for varying learning situations and thus facilitating student attention.

Active Engagement

The summary of Roediger's book "Make it stick: the science of successful learning (2014) is an illustration of the place of active engagement in learning:

“Chapter 2, p 45: To learn, find again!,
Chapter 4: Facing difficulties.”

It's more effective to memorize what you say or do than what you read or hear. The answer lies in the student's level of engagement. The more the student asks questions, rephrases, and looks for answers, the more effective the learning.

What added value for learning? - I

VR necessarily engages students in a new world where they must search, test and manipulate. Gamification can be a very interesting way of constructing pedagogical scenarios that force students to get involved. Distance learning could therefore be enhanced by immersion and interaction. Immersion could make it possible to learn in a playful way, based on a narrative and scenaristic model.

On the model of video games and levels, we could imagine learning scenarios that assume that students who have validated a first experience can reach a higher level of learning. The teacher's pedagogical progression could serve as a guide to enable the immersive pedagogical experience of a higher level.

Immersion could make it possible to learn in a way that appeals to the student's senses. Using experiences involving manipulation or mobilization of the body enables much more effective learning, as it places the learner in a state of embodied cognition. In a nutshell: because the body is mobilized, the brain registers not only the knowledge in question, but also a trace of the physical stimulus that took place.

Regarding embodied cognition, Remy Versace, Professor of Cognitive Psychology at Lyon 2 University, believes that "Even if embodied cognition is still largely unknown in the field of education, more and more teachers are using methods in which they apply the principles of embodied cognition, without necessarily knowing it. This is particularly the case in mathematics: to learn abstract notions, it's useful to link them to sensory experiences, gestures, or representations in space... So that the rules memorized are derived from the pupil's sensorimotor experiences. And this is precisely what Immersive Learning enables. To create sensorial, playful and engaging experiences in the service of pedagogical objectives and a given learning process."

The metaverse, for its part, reduces geographical obstacles and distances, even economic ones, for those involved in the school.

It makes it easier to bring together learners and trainers from the four corners of the world in the same shared space, which can enhance knowledge transmission and learning capacities compared with videoconferencing solutions. As part of a project-based pedagogy, teachers and students can create interactive pedagogical content to stimulate innovation and involve learners in their learning.

What added value for learning? - II

The collection of textual and audiovisual databases in virtual libraries could be organized thematically and, above all, become collaborative.

The metaverse could enable other real-time assessment procedures to be devised, facilitating teachers' work, and reducing the time spent correcting papers, which could then be invested in content development.

Schools in remote or disadvantaged areas to simulate costly infrastructures or experiments.

Feedback

In the learning process, mistakes are normal and often unavoidable. It should not be punished, to avoid inhibition effects, but noticed and pointed out to the learner, so that he can go beyond it and build his knowledge.

In VR, the avatar replaces the learner's persona, making it possible to disinhibit the learner, serving as a screen to de-dramatize the error: it's no longer the learner who makes the mistake, but his avatar.

The feedback students receive when they make a mistake is not seen as a failure, since they can try again as many times as they like. Other students can also follow their classmate on screen and offer advice, as in a Role Playing Game (Zelda, Pokemon, Final Fantasy). More personalized teaching to implement truly differentiated pedagogy within a class group. The metaverse could facilitate collaboration between students and teachers.

Feedback can also come from other individuals in the educational metaverse.

Consolidation

Consolidation anchors learning in the brain. It involves regularly repeating a task in order to "imprint" knowledge over the long term and automate it. This automation is crucial, as it frees up the brain to perform more complex tasks. However, repeating a task can give the illusion of mastery. It is therefore essential that VR experiences are designed not to present identical situations that the learner can repeat, but to vary the parameters and conditions of the situations proposed.

Finally, access to a wide range of training exercises enables the learner to practice and acquire automatisms. The immersive experience could reinforce memorization processes and thus consolidate new knowledge.

Several factors also influence memory anchoring, factors that can be influenced in the design of immersive experiences:

+ Information relevance (pedagogical quality and clarity, fluidity of experience, ergonomics, playability¹⁸...)

+ Interactivity + Sensory stimuli + Emotions + Dejà-vu (contextual similarity)



Chapter 7

Discussion on the Benefits and Challenges of using Metaverse technology in STEM Education

*By Colegio Séneca S. Coop. and
Agrupamento de Escolas de Barcelos*

Introduction

In this chapter we will discuss in general terms the benefits of the application of STEM methodology in teaching, as well as the main challenges faced by both teachers and students when working with this methodology.

To do so, we will begin with a brief review of the history of the development of the STEM methodology from its beginnings and then give a general description of what it is and how it is applied in the classroom.

We will later talk about the benefits that this methodology brings to 21st century education, in which the demand for new methodologies that respond to the demands and needs of students is growing day by day.

But, as with every change in education, there are difficulties to overcome in this aspect such as insufficient teacher training in new methodologies, as well as the lack of human and economic resources in many schools. That is why we will devote the last part of this chapter to reviewing the main challenges facing the implementation of STEM methodology.

Introduction to STEM Methodology

The STEM (Science, Technology, Engineering and Mathematics) methodology has emerged as an innovative educational approach that seeks to integrate these disciplines to promote more holistic and applied learning.

In the context of secondary education in Spain, aimed at students aged 12-16, the implementation of STEM methodology has been shown to have significant impacts on students' academic development and skills.

What is STEM Methodology?

STEM methodology refers to an educational approach that integrates the disciplines of Science, Technology, Engineering and Mathematics. The term "STEM" was established to highlight the importance of the interconnectedness of these four areas in education and real-world problem solving.

Activities and projects based on the STEM methodology seek to foster critical thinking, problem solving, creativity and collaboration among students. This approach seeks to prepare students for 21st century careers and challenges, where skills in science, technology, engineering and mathematics are increasingly important.

Through hands-on projects, experiments and interdisciplinary activities, students can apply concepts learned in these areas in an integrated way. The STEM methodology also highlights the importance of inspiring students' interest in these disciplines from an early age, with the aim of fostering the development of skills that will be valuable in their education and future careers.

The STEM methodology goes beyond traditional teaching by integrating these four key areas into interdisciplinary projects and activities. Students not only acquire theoretical knowledge, but also apply these concepts to real-world situations, fostering critical thinking, problem solving and creativity.

Brief History of the STEM

The STEM (Science, Technology, Engineering and Mathematics) methodology has its roots in the concern to improve education in these disciplines in order to prepare students for the challenges of the 21st century. Although there is no single clear origin, the development of the STEM methodology can be traced through various educational trends and movements over time.

Origins in Science Education

In the early 20th century, attention was focused on improving science and mathematics education in response to the changing demands of industrial society.

During the Cold War in the 1950s, technological competition between the United States and the Soviet Union led to increased investment in STEM education to drive innovation and technological development.

Although the integration of science, technology, engineering and mathematics occurred organically in various educational initiatives, the term "STEM" became popular in the 1990s.

It was initially used in government reports and education policy documents to advocate for greater integration and emphasis on these disciplines.

“Rising Above the Gathering Storm” Report

In 2005, the US National Research Council's "Rising Above the Gathering Storm" Report emphasised the need to improve STEM education to maintain global competitiveness.

The report recommended specific measures, including improving teacher training and encouraging innovation in these areas.

As awareness of the importance of STEM grew, numerous initiatives emerged globally, nationally and locally to promote STEM education.

Educational programmes, competitions, events, and resources were developed to engage students in hands-on and stimulating experiences in science, technology, engineering and mathematics.

Interdisciplinary Approach and Hands-on Projects

The STEM methodology emphasises the interconnectedness between disciplines and promotes an interdisciplinary approach.

Students are encouraged to participate in hands-on projects and activities that integrate science, technology, engineering, and mathematics concepts to address real-world problems.

Brief History of the STEM - I

Impact on Education today

Today, STEM methodology has influenced the revision of educational curricula and pedagogical approaches around the world.

Specialised STEM schools have been established, and many educational programmes seek to incorporate STEM practices at all stages of education, from primary to higher education.

In summary, STEM methodology evolved in response to changing educational and economic needs, and its development has been driven by collaboration between governments, educational institutions, industry, and society at large. The interconnection of science, technology, engineering and mathematics in STEM education seeks to equip students with the skills needed to meet the challenges of the future.

References and relevant authors in the development of the STEM methodology:



National Science Foundation

The NSF has played a key role in promoting STEM. Its report "A Nation at Risk" (1983) highlighted the importance of improving science and mathematics education, laying the groundwork for the STEM approach.



Dr. Seymour Papert

Seymour Papert, a leading educator and artificial intelligence theorist, influenced the idea of student-centred education and learning by doing, fundamental principles in STEM.



Prof. Mae Jemison

As an astronaut and advocate for STEM education, Mae Jemison has championed the integration of these disciplines to inspire and empower the next generation of scientists and technologists.

Benefits of implementing STEM methodology in the classroom

STEM Education has at least the following characteristics:

- Integration of STEM subjects (at least two).
- Problems and lessons must be based on the real world.
- Disciplines are connected through ideas (from each discipline, which are transferable, cross-disciplinary ideas and encompassing ideas).
- To be successful, STEM Education rests on the solid mediation of learning from the subjects that constitute it.

It does not in any way suggest that the whole curriculum should always advance in an integrated way. Many warn of the risk of losing processes and concepts from subjects that are fundamental to building a strong STEM curriculum. Since it is an integrative process, other disciplines such as Language, Arts, Social and Consumer Sciences can be incorporated to contextualise issues and create greater connection in their learning experience.

When carried out effectively, STEM education fosters transversal skills, particularly: critical thinking, problem solving, creativity, communication, collaboration, data literacy, digital literacy and computational thinking.

Several international organisations have underlined the importance of focusing on the generation of certain skills that are particularly relevant for participation in 21st century societies. STEM contributes to the development of these. Additionally, quality STEM education will intentionally integrate social-emotional education skills, for which it is particularly suited, such as providing tools to build healthy identities; manage emotions and achieve personal and collective goals; feel and show empathy for others; establish and maintain supportive relationships; and make responsible decisions. This is not to argue or confuse that it supplements or incorporates it comprehensively; it simply lends itself well to integrating the practice of some social-emotional skills.

Benefits of implementing STEM methodology in the classroom - I

The Collaborative for Academic, Social and Emotional Learning (CASEL) proposes a Social and Emotional Learning (SEL) competency framework in which it sets out five dimensions of competence to be acquired through a variety of formal, non-formal and informal educational experiences:

- Self-awareness
- Self-management
- Social awareness
- Relationship skills
- Responsible decision-making

This framework promotes equity and contributes to the acquisition of learning through authentic partnerships between school, family and community by building the capacities of the school community to be able to deal with various forms of inequity and empower children, youth and adults to co-create thriving environments in their schools that, in turn, foster the building of safe, healthy and fair communities.

Contribution to Sustainable Development

Sustainable development has been described as development that meets the needs of the present without endangering the ability of future generations to meet their own needs. It must have social, economic, ecological, spatial, and cultural viability. To achieve this, it requires focused efforts to build an inclusive, sustainable, and resilient future for all people and the planet, as well as harmonising economic growth, social inclusion and environmental protection which are interconnected and critical to the wellbeing of people and societies.

With culturally sustainable development we emphasise the importance of involving the different social actors of a community as agents of change that commit to actions relevant to their environment and culture, which come from them and are transcendent because they have even become their identity. It is important to stress the need to integrate the following principles in STEM:

- Satisfaction of basic needs.
- Solidarity with future generations.
- Participation of the population involved.
- Preservation of natural resources and the environment in general.
- Creation of a social system that guarantees employment, social security and respect for other cultures.
- Education programmes that generate awareness and sensitivity towards the care and foresight of life on the planet.

Contribution to Inclusion and Equity

It involves the formation of actions and practices of care and service to society that consider the value of human diversity and support a sense of identity that rests on their integration into the social group to which they belong. Accordingly, every human being - regardless of their physical, ethnic, or social condition - has great potential to contribute to society and deserves respect.

The SDG 4 vision of inclusive education encompasses all children, youth, and adults. The Convention on the Rights of Persons with Disabilities in 2006 guaranteed the right to inclusive education "without discrimination and on the basis of equal opportunity, at all levels of the education system, as well as lifelong learning". And, according to UNESCO (2009), inclusive education has a broader scope, as it is considered as a process that takes regard of the diversity of needs of all children, young people and adults, with the aim of removing the barriers that prevent them from having the right to education and reducing the gap of social inequality that has widened with the expansion of the global economy in the countries of the world. Inclusive education involves exploring new teaching strategies and methods to meet the educational needs of all learners, without exception.

As refers to Equity, in the field of education, this means making the fundamental human right to education effective for all in terms of:

- a) Access.
- b) Resources and the quality of educational processes.
- c) Learning achievement. This right is fulfilled by consistently addressing what is necessary to balance the negative effects of the circumstances that have determined structural social inequality and privilege a minority to the detriment of the participation of the majority in social benefits.

Contribution to Active Citizenship

A commitment to being able to collaborate with others in responding to shared challenges, or to take advantage of the opportunities they offer, is essential to transforming the circumstances that block the emergence of a more just society. This means promoting the formation of people who move from consuming goods and services that concern only their individual well-being to transforming their own context for the benefit of all forms of life on the planet. Full citizenship necessarily implies having the fundamental values, competencies, and social responsibilities to actively participate in the changes required by 21st century societies. To guarantee training in these attributes, the barriers of inequality that undermine this possibility should be removed.

The Need for STEM



There are many reasons why a STEM education is highly relevant in the 21st century, even urgent. Scientific thinking and understanding are essential for navigating today's world and society. We need to practice them daily, as they are components of a well-functioning democratic society. Moreover, science is also crucial for a future workforce adequate to the demands of our time.

The World Economic Forum warns of global risks in the short, medium and long term, such as extreme weather events, the failure of cyber security, the disparity in internet access, the loss of biodiversity, the collapse of technology and information infrastructure, the denial of science, some even putting at risk the well-being of millions of people and the survival of humanity itself. These are highly complex, multi-causal risks and challenges that will require transdisciplinary solutions, as well as a great deal of consensus, collaboration, action at different levels of Mexican social and educational life and, without a doubt, a capacity for analysis and systemic action.

In the Brundtland Report, published in 1984, also known as "Our Common Future", perhaps the most prominent words are future, prosperity, justice and security. In addition, 38 years after its publication, the recently published report of the Intergovernmental Panel on Climate Change (IPCC) tells us that recent changes in climate are widespread, rapid, intensifying and unprecedented in thousands of years; that unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, limiting warming to 1.5°C will be impossible; that climate change is already affecting all regions of the Earth in multiple ways; that the changes we are experiencing will increase with further warming; and that the changes we are experiencing will increase with further warming.

It is clear that we need innovation to solve current and future challenges; we need humanised mathematics for technological solutions; we need economists who understand that there are invaluable services in nature, demographers who want to participate in the implementation of climate change adaptation measures; and, most especially, we need collaboration with networks of people involved in education, implementation, public policy, science and technology, because this is how some of humanity's greatest challenges have been solved.

As a generation, girls and boys currently in pre-school and primary school will have to face and, in the best-case scenario, execute in order to reduce the negative impacts of the most important global challenges, such as the biodiversity crisis, the disappearance of species, problems associated with climate change, food security or the acidification of the sea.

The Need for STEM - I



All of this suggests that the educational paradigm needs a 180-degree turnaround, as it has always taken place within four walls; without connection to the natural world; organised entirely by separate disciplines that never or rarely converge; that pretends that learning takes place without context; that favours individualistic learning; that assumes that children learn because it is explained aloud and shown to them without being able to test, manipulate, ask relevant questions and test their hypotheses; that does not even contemplate the reality of the students or the competencies of agency for change as an essential part of growing into full citizens.

Without losing sight of the medium and long term, with the enormous challenges presented by climate change that are becoming more palpable every day, covid-19 has arrived as a variable with profound disruptive implications that have left millions of children without the possibility of attending school or of developing key competencies for their stage of development. Inequity and exclusion are becoming unbearable, and it is necessary to recognise that education must fulfil its role, today more than ever. In the words of the thinker Alfonso Gramsci: "The backwardness of school must be diagnosed by reason of its inadequacy to life"; His thought is opposed to encyclopaedic knowledge, now of the "encyclopaedic internet", as the acquisition of unconnected notions.

Difficulties and challenges facing the implementation of STEM methodology

In recent years, there has been a growing emphasis on Science, Technology, Engineering, and Mathematics (STEM) education to prepare students for the demands of the 21st-century workforce. STEM methodology integrates these disciplines into a cohesive learning approach, fostering critical thinking, problem-solving, and innovation. However, despite its potential benefits, the implementation of STEM methodology in educational settings is not without difficulties and challenges. The following are some of the key obstacles that educators and institutions face when integrating STEM into their curricula.

Lack of Teacher Preparedness

One significant challenge in implementing STEM methodology is the insufficient preparedness of teachers. According to recent studies (Smith & Johnson, 2020; Brown et al., 2021), many educators feel ill-equipped to teach STEM subjects effectively. This lack of preparedness stems from inadequate training and professional development opportunities. To address this issue, educational institutions must invest in comprehensive training programs that equip teachers with the necessary skills and knowledge to deliver STEM education successfully.

Insufficient Resources and Infrastructure

Another major hurdle is the lack of resources and infrastructure required for effective STEM implementation. STEM activities often demand specialized equipment, technology, and laboratories, which many schools may not have access to due to budget constraints (Jones & Smith, 2019). This resource gap disproportionately affects underfunded schools, contributing to educational inequality. Policymakers and school administrators must prioritize allocating resources to ensure that all students, regardless of their socioeconomic background, have equal access to quality STEM education.

Curricular Integration Challenges

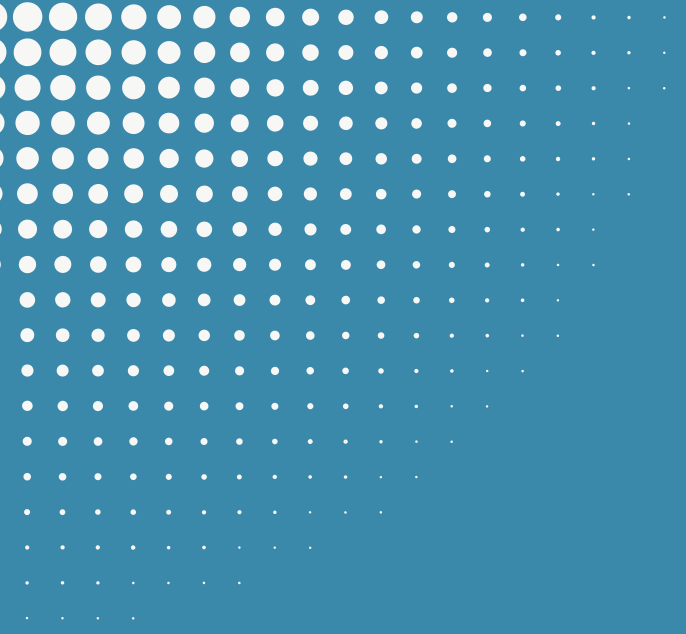
Integrating STEM into existing curricula poses a unique set of challenges. Traditional education structures may not easily accommodate the interdisciplinary nature of STEM subjects. This can result in fragmented teaching that fails to convey the interconnectedness of science, technology, engineering, and mathematics (Bybee, 2018). Successful integration requires a holistic approach that aligns STEM with broader educational goals, fostering a seamless connection between STEM concepts and real world applications.

Difficulties and challenges facing the implementation of STEM methodology - I

Resistance to Change

Resistance to change is a pervasive obstacle in educational settings, and the implementation of STEM methodology is no exception. Educators, parents, and even students may resist the shift away from traditional teaching methods (Henderson & Dancy, 2018). Overcoming this resistance requires effective communication about the benefits of STEM education, demonstrating its relevance in preparing students for future career opportunities and societal challenges.

In conclusion, the implementation of STEM methodology in education is not a seamless process but one fraught with difficulties and challenges. Addressing issues such as teacher preparedness, resource allocation, curricular integration, and resistance to change is crucial for the successful adoption of STEM education. Policymakers, educators, and stakeholders must collaborate to create an environment that supports and promotes STEM learning. By doing so, we can ensure that students are adequately equipped with the skills and knowledge necessary to thrive in an increasingly technology-driven and interconnected world.



Bibliography

Chapter 1

- De Back, T. T., Tinga, A. M., & Louwse, M. M. (2021). Learning in immersed collaborative virtual environments: design and implementation. *Interactive Learning Environments*, 1-19.
- Meccawy, M. (2022). Creating an immersive xr learning experience: A roadmap for educators. *Electronics*, 11(21), 3547.
- Coleman, K., & Derry, B. (2023). Virtual reality in the EAP classroom: Creating immersive, interactive, and accessible experiences for international students. *Language Teaching*, 56(1), 157-160.
- Das, A. (2023, May 3). How To Create Immersive Learning Experiences For Your Learners. *eLearning Industry*. <https://elearningindustry.com/how-to-create-immersivelearning-experiences-for-your-learners>
- Wagner, C., & Liu, L. (2021). Creating Immersive Learning Experiences: A Pedagogical Design Perspective. *Creative and Collaborative Learning through Immersion: Interdisciplinary and International Perspectives*, 71.
- Kuhail, M. A., ElSayary, A., Farooq, S., & Alghamdi, A. (2022, September). Exploring immersive learning experiences: A survey. In *Informatics* (Vol. 9, No. 4, p. 75). MDPI.
- Fonseca, D., Martí, N., Redondo, E., Navarro, I., & Sánchez, A. (2014). Relationship between student profile, tool use, participation, and academic performance with the use of Augmented Reality technology for visualized architecture models. *Computers in human behavior*, 31, 434-445.
- Salvetti, F., & Bertagni, B. (2017). Reimagining STEM Education and Training with e-REAL. *3D and Holographic Visualization, Immersive and Interactive Learning for an Effective Flipped Classroom*. *Int. J. Adv. Corp. Learn.*, 10(2), 63-74.
- Gardner, M. R., & Elliott, J. B. (2014). The Immersive Education Laboratory: understanding affordances, structuring experiences, and creating constructivist, collaborative processes, in mixed-reality smart environments. *EAI Endorsed Transactions on Future Intelligent Educational Environments*, 1(1).
- “Kolb’s Four Stages of Learning - Center for Instructional Technology and Training - University of Florida.” Center for Instructional Technology and Training - University of Florida, <https://citt.ufl.edu/resources/the-learning-process/types-of-learners/kolbs-fourstages-of-learning/>. Accessed 6 Dec. 2023.
- MasterSoft. (n.d.). What is Collaborative Learning? Benefits & Strategy of Collaborative Learning. *Education ERP Campus Software for Schools & Higher Ed | MasterSoft ERP Solution*. Retrieved December 7, 2023, from <https://www.iitms.co.in/blog/what-is-collaborative-learning.html>
- Cakir, M. (2008). Constructivist approaches to learning in science and their implications for science pedagogy: A literature review. *International journal of environmental and science education*, 3(4), 193-206.
- Constructivism - Office of Curriculum, Assessment and Teaching Transformation -University at Buffalo. (2023, April 4). [https://www.buffalo.edu/catt/develop/theory/constructivism.html#:~:text=Constructivism%20is%20the%20theory%20that,%2Dexisting%20knowledge%20\(schemas\)](https://www.buffalo.edu/catt/develop/theory/constructivism.html#:~:text=Constructivism%20is%20the%20theory%20that,%2Dexisting%20knowledge%20(schemas)).

Useful Link:

- For a better insight on Collaborative Learning: <https://www.structurallearning.com/post/collaborative-learning>

Chapter 2

- Tomlinson, C. A. (2017). *How to Differentiate Instruction in Academically Diverse Classrooms*. ASCD.
- Gardner, H. (2006). *Multiple intelligences: New horizons*. Basic Books
- Association for Supervision and Curriculum Development (ASCD). (n.d.). *Differentiated Instruction*. <https://www.ascd.org/topics/differentiated-instruction>
Virtual reality (VR)/ (AR) and ect. <https://en.wikipedia.org/>

Useful Links:

- International Society for Technology in Education (ISTE) – <https://iste.org/>
- Journal of STEM Education (J-STEM) – <https://www.jstem.org/jstem/index.php/JSTEM>
- National Science Teachers Association (NSTA) – <https://www.nsta.org/>
- Edutopia – <https://www.edutopia.org/>
- Journal of Educational Technology Systems (JETS) – <https://www.j-ets.net/>

Chapter 3

- C., & Liu, L. (2021). Creating Immersive Learning Experiences: A Pedagogical Design Perspective. In *Creative and Collaborative Learning through Immersion: Interdisciplinary and International Perspectives* (pp. 71-87). Cham: Springer International Publishing.
- Coleman, K., & Derry, B. (2023). Virtual reality in the EAP classroom: Creating immersive, interactive, and accessible experiences for international students. *Language Teaching*, 56(1), 157-160.
- Das, A. (2023, May 3). How To Create Immersive Learning Experiences For Your Learners. *eLearning Industry*. <https://elearningindustry.com/how-to-create-immersivelearning-experiences-for-your-learners>
- Lemmer, S. (2022, April 28). XR, AR, VR, MR & what's the difference? HYVE. [https://www.hyve.net/en/blog/all-about-virtualreality/#:~:text=Extended%20Reality%20\(XR\)%20refers%20to,the%20interpolated%20areas%20between%20them](https://www.hyve.net/en/blog/all-about-virtualreality/#:~:text=Extended%20Reality%20(XR)%20refers%20to,the%20interpolated%20areas%20between%20them).
- AR, VR, MR, and XR – what they mean and how they'll transform lives. (n.d.). <https://www.qualcomm.com/news/onq/2022/09/ar--vr--mr--and-xr---what-they-mean-andhow-they-ll-transform-li>
- Zhang, C., Perkis, A., & Arndt, S. (2017, May). Spatial immersion versus emotional immersion, which is more immersive?. In *2017 Ninth International Conference on Quality of Multimedia Experience (QoMEX)* (pp. 1-6). IEEE. [https://en.wikipedia.org/wiki/Immersion_\(virtual_reality\)#:~:text=Tactical%20immersion%3A%20Tactical%20immersion%20is,is%20associated%20with%20mental%20challenge](https://en.wikipedia.org/wiki/Immersion_(virtual_reality)#:~:text=Tactical%20immersion%3A%20Tactical%20immersion%20is,is%20associated%20with%20mental%20challenge).
- Yildirim, B., Topalcengiz, E. S., ARIKAN, G., & Timur, S. (2020). Using virtual reality in the classroom: Reflections of STEM teachers on the use of teaching and learning tools. *Journal of Education in Science Environment and Health*, 6(3), 231-245.

Chapter 4

- Cai S, Jiao X, Song B. Open another door to education – Applications, challenges and perspectives of the educational metaverse. *Metaverse* 2022, 3(1): 12 Pages
- Chen Y, Chen Y, Lin W, Zheng Y, Xue T, Chen & Chen G. Application of Active Learning Strategies in Metaverse to Improve Student Engagement: An Immersive Blended Pedagogy Bridging Patient Care and Scientific Inquiry in Pandemic. Department of Scientific research Administration.
- Lopez-Belmonte J, Pozo-Sanchez S, Carmona-Serrano N & Moreno-Guerrero A-J. Flipped Learning and E-Learning as Training Models Focused on the Metaverse. *Emerging Science Journal*. 2022. Vol 6 Special issue
- Mahir P & Hanifah Putri Elisa. Metaverse in education: A systematic literature review. *Cogent Social Social Sciences* (2023). 9:2252656
- Mystakidis, S. (2022). Metaverse. *Encyclopedia* 2022, 2 486 – 497. <https://doi.org/10.3390/encyclopedia2010031>
- Zhang Q. (2023). Secure Preschool Education Using Machine Learning and Metaverse Technologies. *Applied Artificial Intelligence* (2023) vol 37, No 1.
- Zhang X, Chen Y, Hu L and Wang Y. (2022). The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. *Front. Psychol.* 13:1016300. Doi:10.3389/fpsyg.2022.1016300

Chapter 5

- CHALMERS, C.; CARTER, M.; COOPER, T.; NASON, R. Implementing “Big Ideas” to Advance the Teaching and Learning of Science, Technology, Engineering, and Mathematics (STEM). International Journal of Science and Mathematics Education, 2017; HENRKISEN, D.; MISHRA, P. Rethinking Technology & Creativity in the 21st Century Transform and Transcend: Synthesis as a Trans-disciplinary Approach to Thinking and Learning. TechTrends, 2015;
- HSIAO, P.-W.; SU, C.-H. A Study on the Impact of STEAM Education for Sustainable Development Courses and Its Effects on Student Motivation and Learning. Sustainability 2021, 13, 3772 (Google Scholar);
- LUDWIG M., BARLOVITS S., CALDEIRA A. MOURA A., Research on STEM Education in the Digital Age, Proceedings of the ROSEDA Conference, 2023 (Google Scholar);
- <https://manningtutors.co.uk/blog/2023/10/02/exploring-the-importance-of-stem-education-in-the-digital-age/>
- <https://www.nsta.org/nstas-official-positions/stem-education-teaching-and-learning>
- <https://stemeducationjournal.springeropen.com/articles/10.1186/s40594-016-0046-z>

Chapter 6

- Guide l'immersive Learning, France immersive Learning, (téléchargé en décembre, 2023)
<https://www.fil-asso.fr/page/2292868-accueil>
- Mets-toi ça dans la tête!, Peter C. Brown, Henry L. Roediger, Mark A. McDaniel, 2016 pour la traduction française
- <https://www.ifop.com/wp-content/uploads/2022/01/118720-Rapport.pdf>
- <https://www.economie.gouv.fr/metavers-premier-grand-rapport-exploratoire>
- <https://www.polytechnique-insights.com/dossiers/digital/metavers-lespoir-les-promesses-et-lesinconnus/>
- [savons-nous-de-quel-metavers-nous-parlons/](https://www.youtube.com/watch?v=PU8obhkLXR4&ab_channel=EcolePolytechniqueExecutiveEducation)
- [https://www.youtube.com/watch?v=PU8obhkLXR4&ab_channel=EcolePolytechniqueExecutiveE](https://www.youtube.com/watch?v=PU8obhkLXR4&ab_channel=EcolePolytechniqueExecutiveEducation)
- ducation
- https://www.youtube.com/watch?v=ugTFVGRjQ7g&ab_channel=27-ARTE
- https://www.youtube.com/watch?v=WwQNT0S2tJc&ab_channel=PublicS%C3%A9nat
- <https://theshiftproject.org/article/mondes-virtuels-reseaux-publication-rapports-intermediaires/>
- <https://www.inria.fr/fr/virtual-society-metavers-ethique>
- <https://www.lemonde.fr/blog/binaire/2022/02/25/le-metavers-quels-metavers-1-2/>
- Franck Amadiou, André Tricot, Apprendre avec le numérique, Mythes et réalités, Ed Retz, 2020
- Energie, climat : Quels mondes virtuels pour quel monde réel ?, The Shift Project – 2023
- <https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/>
- Guide pratique de l'attention et de la concentration, Complément préambule ATOLE, JL
- LACHAUX, 2018
- <https://project.crnl.fr/atole/system>

Chapter 7

- (World Economic Forum, Marsh McLennan, SK Group and Zurich Insurance Group, The global risks report 2021, en Word Economic Forum [on line], retrieved from http://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2021.pdf, last checked: october, 22nd, 2022.)
- G. Betti, Escuela, educación y pedagogía en Gramsci, Barcelona, Martínez Roca, 1981.
- Brown, A., et al. (2021). Enhancing STEM Education: Strategies for Effective Teacher Professional Development. *Journal of STEM Education Research & Practice*, 22(3), 195-209.
- Bybee, R. W. (2018). *The Case for STEM Education: Challenges and Opportunities*. NSTA Press.
- Henderson, C., & Dancy, M. H. (2018). Physics Faculty and Educational Researchers: Divergent Expectations as Barriers to the Adoption of Research-Based Instructional Strategies. *American Journal of Physics*, 86(1), 9-14.
- Jones, M. G., & Smith, J. A. (2019). *STEM Education Research*. Routledge.
- Smith, L. K., & Johnson, D. R. (2020). Challenges and Opportunities in K-12 STEM Education. *International Journal of STEM Education*, 7(1), 1-10.