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Collaboration and Assessment in Educational Practices with Virtual Reality

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Abstract. This article aims at analyzing experiences of educational practices developed in Brazil at a federal public university using virtual reality, highlighting the strategies used to promote collaborative learning and assessment involving the participation of the students.

Keywords: Virtual Reality, Collaboration, Assessment, Active Learning.

1 Introduction

The metaverse, or virtual reality, is a technology with great potential in today's world according to [26], which highlights the evolution of its applications in various sectors such as gaming, entertainment, business, and also in education, where it has enabled new forms and innovation in teaching and learning processes.

Teaching, learning, and training situations, based on practical experience, find in the metaverse a conducive environment for development due to the high level of interactivity it provides. The combination of Virtual Reality (VR) technology with the Internet of Things (sensors), natural language question-and-answer systems (chatbots), and intelligent assistants are constant possibilities in the list of emerging technologies involving relevant innovations in computing today, as per the Gartner group1 report.

Many companies are exploring virtual reality to create new forms of interaction, collaboration, and entertainment, including the creation of shared virtual worlds where people can explore, participate in activities, socialize, and conduct commercial transactions. [16] and [5] point out that the term metaverse gained prominence around 2020 when the world's largest online social network, Facebook, rebranded itself as Meta, indicating a change in the engagement format of students in the new digital world. Additionally, the rapid shift in teaching modalities in response to the COVID-19 pandemic encouraged educators to involve students in learning through alternative modes of communication and collaboration in a virtual world.

The metaverse, as a fully immersive digital environment, is accessed through an avatar within a digital space-time that is not necessarily equal to the physical world according to [21]. A review conducted by [10] identifies four types of metaverse: augmented reality, lifelogging (activity logging), mirrored world, and virtual reality.

Augmented reality allows overlaying information onto the perceived environment (real or virtual). [17] and [8] report implementations of this metaverse type, involving augmented reality to present overlaid information on remote laboratories, as illustrated in Figure 1.

[1] Gartner's 2015 Hype Cycle for Emerging Technologies Identifies the Computing Innovations That Organizations Should Monitor. Available at: http://www.gartner.com/newsroom/id/3114217.

Fig. 1. Augmented Reality in the AVATAR project.

Lifelogging is a context where people use smart devices to log their daily activities on the Internet or smartphones. In the HIGIA project developed by [22], conversational agents and a pedometer were used in combination with the virtual environment, as illustrated in Figure 2, aimed at motivating obese individuals towards self-care and weight loss. The data captured by the pedometer was processed and displayed in the virtual world, in addition to generating alert and encouragement messages for the user via a virtual agent.

Fig. 2. HIGIA Environment for demonstrations and encouragement of weight loss.

Mirrored world is a simulation of the external world that refers to a virtual model enhanced with information, or a "reflection" of the real world. An example of this type of virtual environment use is described in the work of [20], which led to the creation of an environment aimed at developing professionals' skills for working in manufacturing organizations in the context of Industry 4.0, using virtual reality technologies. Figure 3 shows part of the mechanical assembly room of the VLF (Virtual Learning Factory). An assessment conducted by a group of experts and a user group indicated that activities performed in the mirrored world were rated as "excellent" or "good" representing about 80% of the items.

Fig. 3. Virtual Learning Factory (Rossi, 2021).

The fourth type of metaverse, virtual reality, is a metaverse that simulates a virtual world, including sophisticated 3D graphics, avatars, and instant communication tools. It is a world where users immerse themselves in a virtual reality. It is also characterized as an Internet-based 3D space that multiple users can access simultaneously and participate through an avatar. Virtual reality is also called metaverse in the strict sense, as daily and economic activities can take place in the virtual space.

Thus, while the market demands individuals capable of doing and solving problems, that involve experimenting with solutions, traditional education in schools, universities, and even in certain Latin American vocational courses is based on theoretical studies of principles and theories. Several factors contribute to this scenario, where students do not always have direct access to laboratories for their learning experiments. Predominant reasons include personal or environmental risks involved, especially the economic issue of financial costs in Latin America. Therefore, contextualization and application examples of what is being studied usually appear in the form of examples that students passively watch without direct and active involvement. To avoid this type of limitation, it is necessary to rethink the educational system and explore new possibilities as noted by [27].

Virtual reality environments can be alternatives to mitigate potential personal and environmental risks during teaching and learning processes because, according to [11], experiments can be carried out, and the consequences of errors that naturally occur during testing can be faced and treated without the costs and harmful effects that could occur in real situations.

The use of the metaverse in education is developing and evolving. There are several emerging trends, including the use of immersive learning; collaboration and social interaction; personalized learning experiences; virtual field experiences; simulation and modelling. These possibilities are especially relevant for educational contexts where there are not enough economic resources to afford active learning experiences involving experimentation in laboratories or expenses for field trips, which are important to contextualize learning focus and bring examples of knowledge usage being worked on. In this sense, society, and education with it, is already embracing this new virtual world through metaverse courses conducted by universities according to [5].

There is ample evidence of educational efficiency regarding the use of the metaverse. [14] and [13] present a study with a sample of 102 high school students in which the immersion principle in multimedia learning was described and investigated. The study involved conducting a virtual field trip, a virtual world through a Head-Mounted Display (HMD) or a 2D video as an introductory class in the context of an intervention on climate change based on research from six lessons. The HMD group scored significantly higher than the video group in presence ($d = 1.43$), enjoyment ($d = 1.10$), interest ($d = 0.57$), and retention in immediate ($d = 0.61$) and delayed post-tests ($d = 0.70$). That is, the study contributed to understanding the immersive cognitive-affective learning model and suggested that immersive classes can have positive long-term effects on learning.

According to [5], with the use of tools such as virtual reality glasses or augmented reality devices, teleportation to a new world within the metaverse will be achieved. However, virtual reality technology for the Latin American economy context is also a cost to be considered in implementation for educational purposes, especially when VR solutions involve additional equipment such as HMD - Head Mounted Display. This is why the use of such equipment cannot be seen as the only technological option, and alternatives involving semi-immersiveness need to be considered and have value as an educational resource, as pointed out in [7].

The assessment of teaching and learning processes is fundamental to verify the use of virtual reality as an educational tool and can occur in relation to: (a) students' prior knowledge before their immersion in the metaverse; (b) learning outcomes after interaction with virtual reality; and (c) the learning process itself. Learning outcome assessments can be carried out through retention and transfer tests. But other factors such as the impact of VR use on student motivation, which can have a lasting effect extending beyond the time of VR environment use, leading to greater student interest in the thematic studied in the conceptual field, must also be considered. An example of the result of using VR environment can be achieved through the use of virtual tours that bring relevant aspects of the studied context to students to stimulate their interest and curiosity about the topic.

[27] used evaluation through questionnaires and objective instruments, involving tracking student activities in the virtual world, associating with questionnaires that assessed their Flow state, allowing diagnosis and identification of metaverse resources and activities with better potential to achieve that state. According to [4], the Flow state occurs when the experience is intrinsically rewarding, and life is justified in the present rather than being dependent on a hypothetical future gain. This is highly desirable because it is a subjective state in which people report being completely absorbed in something to the point of forgetting time, fatigue, and everything else, with intense experiential involvement in an activity. As a result, their cognition can be influenced, and their performance quality enhanced. The research by [27] showed that, analysing the Flow dimensions in the evaluated groups, it was possible to verify that the students perceived the "Loss of reflective self-awareness" and "Autotelic experience" dimensions more intensely in their Flow experience. Regarding learning gain, a positive correlation was observed between the Flow state and performance in online tests, between the Flow state and the Post-Test result, and between the Flow state and the difference between Pre-Test and Post-Test.

Given this scenario, this article aims to analyze experiences of educational practices using the metaverse with semi-immersive experience carried out in Brazil at a federal public university. The first analyzed experience is a project called AVATAR - Virtual Learning and Remote Academic Work Environment by [25], which sought to investigate, test, and promote training for the creation and use of virtual laboratories in immersive environments.

The project aimed to stimulate the development of virtual laboratories in the immersive Open Simulator[2] environment, an open-source software that implements an open environment in which it is possible to add scenarios composed of virtual artifacts that can be handled by users.

The second educational practice analyzed in this article was developed in the Graduate Program in Informatics in Education at the Federal University of Rio Grande do Sul, in Porto Alegre, Rio Grande do Sul, Brazil, with doctoral students from the Collaborative Learning Supported by Computer subject, using the CoSpaces.Edu virtual environment. The educational activity aimed to empower students to create interactive virtual environments for their teaching areas.

2 Active Learning in Virtual Reality Environment

The use of immersive technologies for education is increasing due to their potential to complement current methods of delivering learning content to students, promoting active, experiential, and higher-order learning. [6] states that active learning is within a process of social and conceptual development based on knowledge discourse, differing in this aspect from constructivist theory. The author also emphasizes that the theory provides a learning model that motivates students to work together to learn and create knowledge, where collaborative theory defines learning as intellectual convergence.

[12] presents an Augmented Reality (AR) application focused on the literacy process of children in Brazil - the Alfabetiza-AR app. The research introduces the initial results of evaluating the application, developed using Unity and Blender tools, by a group of literacy teachers engaged in active learning processes. The research highlights several key findings, including the app's appeal to children and its ability to motivate them, along with the potential for integrating its use into existing teaching plans. The efforts of these teachers are particularly significant for Brazil, given that children's literacy challenges represent a major educational hurdle in the country.

[2] presents the results of a study that used the metaverse as an active learning environment for hybrid teaching. In the study with students engaged in two subjects in the Information Systems course at a federal university in Brazil, the Gather Town environment was used to develop activities. The environment and the results produced in the active and collaborative learning process were assessed using two questionnaire models: i) TAM (Technology Acceptance Model) aiming to assess the ease and motivation of using a technology; ii) COLLES (Constructivist Online Learning Environment Survey) seeking to determine students' perception of an environment regarding its pedagogical principles. The main published results suggest that the technology was considered easy to use and useful for carrying out activities in the hybrid teaching context, an environment suitable for online learning as it enhanced collaboration and interpretation. Furthermore, it was considered by students as a motivating and engaging factor for completing the proposed tasks. After the COVID-19 pandemic, distance education and hybrid teaching models grew significantly in Brazil, but they still lack the development of methodologies and technologies that increase interaction among students in learning environments, where the metaverse can positively contribute in this regard.

As highlighted by [1], access to quality education is still a major challenge in developing countries, and educational multimedia offers an alternative to provide resources capable of attracting and engaging students. Considering that in a virtual reality environment multimedia presence is key, it is important that such environment projects pay attention to the peculiarities and impacts of multimedia on learning.

Multimedia learning, according to the Cognitive Theory of Multimedia Learning (CTML) developed by [13], refers to promoting learning from words (printed or spoken form) and images (static graphics like illustrations, charts, photos, and maps, or dynamic graphics like animations and videos). The argument for multimedia learning is based on the premise that students can better understand an explanation when it is presented in words and images than when presented only in words. Multimedia learning can be used as: (a) response reinforcement (in exercise and practice systems); (b) information acquisition (information delivery); or (c) knowledge construction (cognitive aid).

In this context, metaverse technology is especially conducive to achieving multimedia learning, and CTML is also based on the concept of cognitive load by [24], which understands that information overload generates cognitive overload in the human brain, impairing understanding of the information to be learned, and thus meaningful learning occurs only when the amount of information presented is within the limit of the brain's comprehension capacity. Cognitive overload can be derived from: extraneous cognitive load, or load unrelated to educational content; intrinsic cognitive load, natural to the complexity of educational content being learned; and germane cognitive load, resulting from teaching activities related to the process of making sense of material that benefits

[2] Open Sim - http://opensimulator.org/wiki/Main_Page.

learning objectives. The sum of these three cognitive loads may exceed the student's cognitive capacity, leading to learning failures.

Under the premise that it is necessary to reduce extraneous cognitive load, manage intrinsic cognitive load, and promote germane cognitive load, [13] has developed a set of principles known as multimedia learning principles that should be applied in designing and constructing educational environments. The multimedia learning principles aim to reduce cognitive load and are grouped into three categories.

The principles category to reduce extraneous cognitive load involves: a) Coherence - Exclude words and pictures irrelevant to the learning theme; b) Signalling - Highlight essential words and graphics related to the content to be learned; c) Redundancy - Exclude redundant captions from narrated animation (in audio); d) Spatial contiguity - Place essential words close to corresponding graphics or pictures; and e) Temporal contiguity - Present corresponding words and images simultaneously.

The second category of principles involves managing intrinsic cognitive load: a) Segmenting - Divide a long lesson into smaller segments; b) Pre-training - Provide students with pre-existing concepts and terminology related to the subject being learned; and c) Modality (dual) - Use narration preferably to written text to accompany images.

Finally, the third category of principles concerns promoting germane cognitive load, inherent to the learning process itself, and includes: a) Personalization - The agent on the screen should display gestures, movements, eye contact, and facial expressions similar to humans; b) Voice - Human narration voice is preferable to computer-synthesized voice; c) Image - The instructor's static image should not be displayed on the screen; d) Embodiment - The animated or recorded instructor should embody human gestures and movements; e) Immersion - The sensory experience of virtual reality used should be critical to the task; and f) Generative activity - Students should be encouraged with generative activities (active learning) such as summarizing, drawing, imagining, self-testing, self-explaining, mapping, acting, and teaching.

Several strategies for active student participation are possible, and the metaverse allows supporting this type of work. [13] recommends promoting generative processing by using activities that involve active student participation. These activities can be carried out individually or collaboratively. Given the complexity of any generative activity in the VR environment, collaboration is advisable, and strategies to facilitate this collaboration need to be analysed as they differ from environment to environment. By promoting collaboration, students are challenged to develop their activities in small workgroups. Knowledge is constructed in a shared manner among students and mediated by the teacher, responsible for fostering interaction and collaboration among students.

When working actively in a metaverse environment, different tools can be used. Besides actions that provide autonomy, engagement, and discussion, the metaverse environment can facilitate peer interaction, collaboration, and group development as a whole.

In 2023, within a Computer-Supported Collaborative Learning subject at the Graduate Program in Informatics in Education at the Federal University of Rio Grande do Sul, in Brazil, a set of activities was provided to develop collaborative learning among students using various digital tools to create educational virtual spaces on the CoSpaces.edu3 platform. The platform facilitates the creation of tours using 360-degree scenarios, interactive stories, visits to exhibitions, games, and simulations. It also allows the inclusion of internal and external objects (3D objects, links to videos and web pages) and the development of scripts for the artifacts included in the virtual space, which can be done using the visual block programming language, CoBlocks, designed for easy learning by students or teachers without a background in computing.

One of the projects worked on involved the collaborative construction of a virtual space containing a tour aimed at developing knowledge related to a virtual field selected by the students themselves, using the CoSpaces.edu platform that can be used on desktop computers, tablets, and smartphones (with or without a Head Mounted Display). To provide an effective collaborative environment among students, especially for them to acquire knowledge about CoSpaces.edu tools and related technical concepts, the Moodle virtual teaching and learning environment was used as a support, where support resources (scaffolding) were made available, as proposed by [19], and in the context of virtual reality by [18]. These resources also aimed to provide pre-training in the strategy for managing more complex intrinsic cognitive load, inherent to the creative process in a VR environment, as proposed by [13].

Social networking tools (WhatsApp and email) were also used to expand peer support in training participants to operate in this environment, troubleshoot difficulties, and make decisions regarding the collaborative construction of the virtual space. As advocated by [28], social communication fosters learning. To support collaborative learning, various activities were proposed to be carried out on Moodle, such as a glossary to record related concepts and terminology, collaborative wikis, forums for information dissemination, a database for depositing

[3] Cospaces edu - https://www.cospaces.io/

examples of virtual spaces developed on CoSpaces.edu, in addition to tasks. An external tool, Padlet4, was used to record students' reflections on the collaborative process of building the virtual space.

The Trello5 platform was also used to record and monitor communication processes and manage activities. This tool is a project management tool that allowed monitoring individual contributions of each group member to the joint construction of the group, as well as visualizing the progress of tasks necessary to complete the project.

One aspect to highlight is that CoSpaces.edu allows students to co-create within the same project, enhancing collaborative learning as multiple students can simultaneously build codes, scenarios, and dialogues for the educational tour in the developed project. The CoSpaces.edu Classes functionality allows the creation of tasks that can be assigned to groups of students. Thus, both the teacher and group members can inspect and collaborate on the construction of the virtual space.

3 Evaluation in the Virtual Reality Environment

Among the benefits of VR for education is its ability to promote active, experiential, and higher-order learning. However, what is still unclear to educators is how to measure learning in immersive environments. According to [21], there are several challenges and opportunities that the metaverse presents to education as a means to foster a more relevant and effective teaching process, which necessarily involves developing both the implementation and monitoring of educational research in the metaverse environment.

Evaluation is an essential task in teaching practice as it aims to verify whether the proposed objectives have been achieved or not. Through it, the results obtained during the work between teacher and student can be compared with the proposed objectives to be achieved, thus assessing students' progress and difficulties. The evaluation process tends to be quite subjective, requiring clear and well-defined specific evaluation objectives. When conducted in a virtual reality environment, it can be developed in various ways. [29] proposes a framework to guide educators in the design and implementation of assessments using immersive technologies. The evaluation framework presented in their work is based on the constructivist theory of learning, which relies on the Constructive Alignment (CA) principle and the Evidence-Centred Design (ECD) structure. The proposal shows an assessment framework based on games developed to guide educators in designing appropriate assessment tasks to measure learning in immersive environments. CA recommends starting with the intended learning outcomes when designing assessments, ensuring that the outcomes, assessment tasks, and chosen learning and teaching activities are aligned. For this purpose, there is a need to develop useful instruments to assess learning outcomes, student characteristics, and learning processes.

In the use of biosensors to evaluate the impact of VR on users, there are solutions that allow monitoring eye movements, brain activity, and other physiological data captured during learning.

Biosensors are commonly used in research applied in other areas; however, in recent years, they have shown significant results when used to evaluate environments rich in educational media. In [8], Mind-Wave Mobile 2 - Neuro Sky devices were used. This device uses EEG (Electroencephalogram) techniques to record neural oscillations discharged by the user's brain through their dorsolateral prefrontal cortex. It has been demonstrated that multimedia resources can positively contribute to student engagement. By analysing student action records, researchers observed that interaction with educational media promotes a positive difference in students' focused attention, especially those that allow active experimentation, such as simulations. The authors collected student attention levels through EEG during the use of two educational platforms, proving that levels of inattention were three times lower and attention levels were four times higher when students had the opportunity to interact with the platform containing multimedia educational resources in a virtual reality environment.

Student reaction evaluation can be facilitated through questionnaires and objective instruments, as described in [27]. The research conducted by the author used a portable version of OpenSim. Using other support tools, it was possible to record information derived from student activity in a database and create PHP pages to access this data. To obtain information before and after using the Virtual Educational Laboratory, five questionnaires were established: Student Profile, Pre-test, Post-test, Flow, and Virtual Educational Laboratory Evaluation. The research used the LONG Flow State Scale-2 proposed by [3], which allows evaluating the Flow experience from nine dimensions: balance between challenges and skills, fusion between action and awareness, clear goals, immediate feedback, intense and focused task concentration, sense of control, loss of reflective self-awareness, distortion of time experience, and autotelic experience. In four levels, the results achieved were above average. From the results, it was possible to ascertain that the virtual environment absorbed the student's attention to such an extent that they felt teleported to the Virtual Educational Laboratory, and the experience was so pleasant that the

[4] Padlet - https://padlet.com/

[5] https://trello.com/

student was only interested in what they were doing, to the point of feeling integrated with the 3D virtual environment. The level of reflective self-awareness loss observed was the highest, reaching 4.17 (with SD 0.7) on a scale of 0 to 5 (Likert scale).

Regarding the experiment conducted with students from the Graduate Program in Informatics in Education at the Federal University of Rio Grande do Sul, Brazil, the evaluation aspect of the activity's outcome developed by students, both individually and collaboratively, was addressed. To avoid subjectivity in evaluation, especially when involving peer evaluation, the use of rubrics proved to be a good strategy. Rubrics to assess virtual spaces created by students can be developed and used by the student as a guide to check if their result meets the criteria to be evaluated, even if the evaluation itself is done by the teacher or peers. Thus, students know in advance what is expected of them regarding the construction of a satisfactory educational virtual space.

Table 2 shows an example of rubric for evaluating a task involving the construction of a virtual space for presenting a story developed by the 5 students participating in the activity, whose ages were 32, 40, 42, 51, and 53 years old, all with completed academic master's degrees and some previous experience in building scenarios in virtual environments.

Table 1. Rubric for evaluating virtual space with a story.

Scenario	No scenario provided 0 points	Scenario unrelated to the story context 1 point	Scenario consistent with the story 2 points
Characters and Objects	1 character and 1 or 2 non-animated objects 0 points	2 to 4 non-animated characters and objects 1 point	2 to 4 animated characters and objects 2 points
Interactivity	No interactivity 0 points	Interaction options and movement of characters and objects 2 points	Creative and varied interaction and movement with characters and objects 3 points
Educational Use	No perceived educational use 0 points	Basic educational use with mere presentation of facts aimed at meeting Bloom's Taxonomy level 1 objectives 2 points	Creative educational use aiming to meet educational objectives of Bloom's Taxonomy levels 2 to 4 3 points

The results indicated that it is possible to promote collaboration through an activity developed in a metaverse environment. Before carrying out the collaborative activity, the students received all the guidance on how to explore CoSpaces.edu and its functionalities. The information was provided in guidance scripts to be explored prior to classes. During class, simulations and situations were conducted to use the learned resources, and students could ask questions, consult materials available on the Moodle platform, and interact with other classmates and teachers.

Afterwards, they were tasked with collaboratively creating a story in the metaverse environment, using the acquired knowledge and the collaborative learning approach. The task was assessed using a previously provided evaluation rubric on the Moodle platform, allowing students to review the topics they needed to develop and how they would be evaluated.

Besides knowing how to use the tool's functionalities and having a good script, students also needed to organize and manage tasks collaboratively, supporting each other, exchanging ideas and contributions. In this specific activity, the group used WhatsApp for communication. At the end of the activity, students reflected on the difficulties in negotiating within the group and the constant need for communication among peers to advance with the task. They also noted the roles of students who coordinated actions within the groups, organizing activities, suggesting changes, and managing deadlines.

In the Moodle virtual learning environment, various activity types allow the use of rubrics (assignments, forums, quizzes, databases, glossary, and some parts of lesson activities) for assessment, but not all allow peer assessment. For instance, the assignment activity allows the use of rubrics and evaluation by students whose permission has been changed to evaluator. However, only one student can evaluate an assignment completed by a peer. To enable all group members to evaluate tasks performed by peers, it is necessary to use the Moodle workshop activity. This evaluation results in two grades: one for the evaluated student, resulting from the average of their peers' evaluations, and another derived from the accuracy of each student's evaluation. An evaluator's assessment on each question is considered correct when the majority of evaluators choose that option.

4 Conclusions

The use of Virtual Reality environments in education is growing as it offers advantages in terms of providing students with resources and experiences that would otherwise not be feasible to use. In some cases, such as at Nagoya University in Japan, a complete virtual campus is being built that mimics a real university, containing replicas of buildings with classrooms and laboratories. The idea is to provide a sense of presence and interactivity that is not usually so present in online activities. These benefits - derived from the use of VR - have been observed in experiments, and the positive impact on learning comes not only from immersion in a multimedia-rich context but also from the opportunities for student engagement in challenging activities that can induce a state of flow, increasing attention and motivation, which are basic variables for better quality learning. The handling of artefacts available in the virtual world is a basic element in increasing motivation, and the possibility of interaction with peers also contributes to increased potential for cognitive growth, as advocated by [28] with the concept of ZPD - Zone of Proximal Development.

Although there are studies indicating that VR can promote learning of complex material, develop creativity, as well as problem-solving and metacognition skills, there are not yet many experiments involving participatory and collaborative methodologies [23].

This article presented examples of projects that tested the educational use of semi-immersive Virtual Reality solutions involving active student participation, collaboration, as well as assessment strategies involving the students themselves. Such strategies show a path that can be pursued at a lower cost, which is important for educational institutions in Latin America. These experiments have shown that both Virtual Reality and the CoSpaces.edu metaverse environment enable working in a safe environment for students, without risks, without the need for physical space and investment in laboratory materials, additionally promoting new forms of collaboration, socialization, and shared entertainment, where students demonstrate a higher level of attention.

Collaborative learning is a possibility for both experiments, favouring cognitive and socio-emotional development, and allowing assessment to be non-subjective, as students themselves can participate in the process, check the topics that will be assessed and observe whether the initial objectives were truly addressed.

Thus, it is believed that Virtual Reality and the experiments presented can be an alternative pedagogical activity for teachers, aiming for students to learn collaboratively, actively from a more engaging and effective teaching process.

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References

1. Abdulrahaman, M. D., et al.: Multimedia tools in the teaching and learning processes: A systematic review. Heliyon, v. 6, n. 11, p. e05312 (2020). https://doi.org/10.1016/j.heliyon.2020.e05312.
2. Classe, T.M., Castro, R.M., & Oliveira, E.G.: Metaverso como Ambiente de Aprendizagem Ativa para o Aprendizado Híbrido. Revista Brasileira de Informática na Educação, 31, 222-254 (2023). DOI: 10.5753/rbie.2023.2908.
3. Csikszentmihalyi, M. F.: The Psychology of Optimal Experience. HarperCollins Publishers, New York (1990).
4. Csikszentmihalyi, M.: Flow and Education. In: Applications of Flow in Human Development and Education. Cap. 6. Springer: Dordrecht (2014).
5. Contreras, G. G., Serrano, M., Martinez, C., C. Escobar, J.: The importance of the application of the metaverse in education. Modern Applied Science, v. 16, n. 3, p. 1-34 (2022).
6. Harasim, L.: Learning Theory and Online Technologies. 2ª ed. Routledge. New York (2017).
7. HE, H. et al. Outdated or Not? A Case Study of How 3D Desktop VR Is Accepted Today. In: International Conference on Immersive Learning. Cham: Springer Nature Switzerland, 2023. p. 150-160.
8. Herpich, F., Guarese, R. L. M., Cassola, A. T., Tarouco, L. M. R.: Mobile Augmented Reality Impact in Student Engagement: an Analysis of the Focused Attention Dimension. International Conference on Computational Science and Computational Intelligence (CSCI), 562-567 (2018).

9. Herpich, F., Vanucci Costa Lima, W., Nunes, F. B., Lobo, C. de O., & Tarouco, L. M. R.: Atividade educacional utilizando realidade aumentada para o ensino de física no ensino superior. Revista Iberoamericana de Tecnología en Educación y Educación en Tecnología, (25), 68-77 (2020).
10. Kye, B. Han, H. Kim, E. Park, Y. Jo, S.: Educational applications of metaverse: possibilities and limitations. Journal of educational evaluation for health professions, v. 18 (2021). https://doi.org/10.3352/jeehp.2021.18.32.
11. Le, Q.T., Pedro, A. & Park, C.S.: A Social Virtual Reality Based Construction Safety Education System for Experiential Learning. Journal of Intelligent and Robotic Systems: Theory and Applications, 79, 487–506 (2015). https://doi.org/10.1007/s10846-014-0112-z.
12. Lima, M. B., Araújo, M.J.R., Corrêa, S.J.C.: Desenvolvimento de aplicativo de Realidade Aumentada para auxílio no reconhecimento das letras no processo de alfabetização infantil: um estudo no ensino fundamental menor. Revista Brasileira de Informática na Educação – RBIE, 31, 602-630 (2023). DOI: 10.5753/rbie.2023.2916.
13. Mayer, R.: Multimedia learning. New York: Cambridge University Press (2021).
14. Makransky, G., Mayer, R.E.: Benefits of Taking a Virtual Field Trip in Immersive Virtual Reality: Evidence for the Immersion Principle in Multimedia Learning. Educ Psychol Rev 34, 1771–1798 (2022). https://doi.org/10.1007/s10648-022-09675-4.
15. Nagao, K.: Virtual reality campuses as new educational metaverses. IEICE TRANSACTIONS on Information and Systems, v. 106, n. 2, 93-100 (2023). DOI: 10.1587/transinf.2022ETI0001.
16. Ng, D. T. K.: What is the metaverse? Definitions, technologies and the community of inquiry. Australasian Journal of Educational Technology, v. 38, n. 4, 190-205 (2022). https://doi.org/10.14742/ajet.7945.
17. Nicolete, P. et al.: Analysis of Learning Styles of Students Enrolled in a Technical Course in Electromechanics with the Application of the Inventory of Kolb. Tecné, Episteme y Didaxis, TED 53 (2023): 63-81.
18. O'Connor, E. A., Worman, T.: Designing for interactivity, while scaffolding student entry, within immersive virtual reality environments. Journal of Educational Technology Systems 2019 47:3, 292-317 (2019).
19. Reiser, B.J.: Scaffolding complex learning: The mechanisms of structuring and problematizing student work. Scaffolding. Psychology Press, 273-304 (2018).
20. Rossi Filho, T. A.: Um método para o desenvolvimento de competências para a indústria 4.0 através de tecnologias de realidade virtual. Tese. Informática na Educação / UFRGS. Porto Alegre. (2021).
21. Sá, M.J., Serpa, S.: Metaverse as a Learning Environment: Some Considerations. Sustainability 15 (3), 2186 (2023). https://doi.org/10.3390/su15032186.
22. Sgobbi, F., Tarouco, L.M.R., Reategui, E.: The Pedagogical Use of the Internet of Things in Virtual Worlds to Encourage a Behavior Change in Obese Individuals, 2017 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), Exeter, UK,. 676-682 (2017).
23. Southgate, E.: Teachers facilitating student virtual reality content creation: Conceptual, curriculum, and pedagogical insights. In: Immersive education: Designing for learning. Cham: Springer International Publishing, 189-204 (2023). https://doi.org/10.1007/978-3-031-18138-2_12.
24. Sweller, J.: Cognitive Load Theory. Psychology of Learning and Motivation, p. 37–76 (2011) https://doi.org/10.1016/B978-0-12-387691-1.00002-8.
25. Tarouco, L.M.R., Sila, P., Herpich, F.: Cognição e aprendizagem em mundo virtual imersivo. 2a ed. Editora UFRGS, Porto Alegre, RS (2020). Available at: https://www.lume.ufrgs.br/handle/10183/210290.
26. Tarouco, L. M. R., Machado, L. A. L. M., Silva, T. L., Timóteo, D. J. A..: Possibilidades do Metaverso como Recurso Educacional. Revista da FUNDARTE, v. 56, n. 56, 1-22 (2023).
27. Tibola, L., Tarouco, L. M. R.: Laboratórios educacionais virtuais como promotores do estado de flow e da aprendizagem ativa. Revista Novas Tecnologias na Educação, Porto Alegre, v. 16, n. 2, 220–229 (2018). https://doi.org/10.22456/1679-1916.89305.
28. Vygotsky, L. S.: Mind in society: The development of higher psychological processes. Harvard University Press, Cambridge, MA (1978).
29. Udeozor, C. Dominguez, J. Glassey, J.: Assessment Framework for Immersive Learning: Application and Evaluation. In: Bourguet, ML., Krüger, J.M., Pedrosa, D., Dengel, A., Peña-Rios, A. Richter, J. (eds) Immersive Learning Research Network. iLRN 2023. Communications in Computer and Information Science, vol 1904. Springer (2023). https://doi.org/10.1007/978-3-031-47328-9_15.