Meta-Mate: A VR Escape Room for the Study of Integrals

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***Abstract*—In order to improve traditional education, technological solution are often used to overcome the limitations of the physical world and provide comprehensive and engaging learning experiences. Specifically, several studies showed that immersive technologies, such as Virtual Reality (VR), can be used to create enjoyable experiences where the study of difficult topics, i.e., abstract and complex concepts typical of mathematics education, is facilitated. This result is usually associated with the immersion and the high sense of presence that is characteristic of VR applications. Additionally, the combined use of VR and gamification methods, such as challenges, rewards, and a coherent narrative, can further enhance the overall engagement and enjoyment associated with the immersive experience, thus leading to more fulfilling and effective learning solutions.**

Starting from these considerations, the aim of this paper is to present a VR escape room where students can learn the main concepts of integration and differentiation in a novel and engaging way. The devised VR application, that was designed with the help of mathematics teachers to focus both on the correctness of the presented topics and on the overall effectiveness of the learning experience, consists of a virtual environment where students can progressively explore the concept of integral through a series of challenges (integration and differentiation, antiderivative, integration by substitution, integration by parts, definite integrals, mean value theorem, solids of revolution).

The VR escape room was tested with high school students, and its evaluation was conducted through a user study leveraging both subjective and objective measures.

***Index Terms*—virtual reality, escape room, gamification, mathematics, learning**

I. INTRODUCTION

In recent years, it has been possible to witness a collective effort, both from scholars and teachers, towards the research and development of alternative solutions able to improve existing learning experiences. This is particularly true in the context of mathematics education, a discipline that is often deemed difficult and can lead to the development of anxiety in the students [1] due to its complexity and the abundance of abstract concepts that are often hard to grasp. Consequentially the design and implementation of new, engaging and enjoyable approaches for the representation and visualization of abstract concepts is of paramount importance.

A viable solution for the improvement of traditional education is the integration of technology [2]–[4], which enables the creation of enhanced instructional delivery modules and aiding tools [5], such as authoring systems for the assessment of learning activities [6]. Among the several instances of technology-enhanced education [7], [8], it is possible to observe a proliferation of studies and applications dedicated to STEM education [9], and specifically mathematics and geometry [10]. In this field, technology can improve the visualization of abstract and complex concepts [9], [11], e.g., through the use of desktop applications, and can be associated with a positive influence on student engagement and learning outcomes [12].

In this scenario, the use of immersive technologies, and specifically Virtual Reality (VR), can be particularly effective, mainly due to the elevated immersion and sense of presence (often associated with higher engagement [13]) that characterize VR experiences. Specifically, several studies confirmed the general positive outcomes of VR technology in mathematics education. The authors of [14] explored the use of VR for learning three-dimensional mathematical concepts (i.e., volume calculation and points definition), showing that using the VR application was associated with better performance and an increased learning motivation w.r.t. a traditional lesson. Moving to a more theoretical scenario, in the study conducted by Yi-Chen Hsu [15] it was possible to observe that a VR-based approach can lead to improved learning motivation and learning effectiveness over traditional, non technology-enhanced education.

The advantages of VR are particularly evident when immersive technologies are compared to more classical technological solutions, such as the use of desktop applications. The authors of [11], for example, investigated the impact of VR technologies on the quality of learning experience, contrasting three approaches (physical, desktop-based and VR) that were comparable in terms of learning outcomes. The study focused on an activity heavily based on geometrical and mathematical concepts (i.e., the calculation of the space curvature in the proximity of a black hole), and showed that the use of VR was associated with several qualitative advantages over the other solutions, being more effective than the desktop approach in overcoming the limitation of the physical approach and being, overall, the most enjoyable solution. This showed that VR can be considered a valuable alternative for the organization of learning experiences, and was possible due to the intrinsic characteristics of the VR technology, that enabled the creation of an experience where students where able to move and immerse in a 3D space that was not hindered by the limitations and obstacle of the physical world.

Finally, to further improve over traditional education it is possible to combine VR technologies with gamification methods, leading to the creation of immersive learning solutions that are effective, and even more engaging and enjoyable. As seen in the literature, in fact, by associating the expected learning outcomes to specific, interactive gameplay elements [16], by encoding the concept of cause-and-effect in the game mechanics [17], and by introducing psychological models to keep players engaged [18], it is possible to create effective, VR serious games that offer a coherent narrative and can be enjoyed by the target user [19].

Based on all the aforementioned considerations, the aim of this paper is to devise an immersive application to facilitate the study of integrals for students in secondary education, providing an engaging virtual environment characterized by elements of gamification (namely, a VR escape room) where it is possible to practice and exercise on several aspects of the tackled topics. Despite the several studies on the use of VR for mathematics education, in fact, its use for the study of integrals is still under-investigated. The application was designed in collaboration with mathematics teachers and was later tested and preliminary evaluated with students from the High School ”25 Aprile - Faccio”, Cuorgnè (TO). All the topics and aspects that are included in the application are based on teaching supplements, such as books [20] and slides, actively used in classes in Italian secondary education.

II. Background

A. Integrals in Secondary Education

In mathematics, an *integral* is the inverse operation of the differentiation [20]. Given a function $f(x)$, its indefinite integral is written as:

$$\int f(x)\,dx$$

where the $\int$ sign represents the integral operation, $f(x)$ is called the *integrand* function, and the dx symbol, also called the *differential*, indicates that x is the variable of the integration. This indefinite integral represents all the functions whose derivative is the considered integrand function $f(x)$. For instance, $\int x^a\,dx = \frac{x^a+1}{a+1} + C$, where C is the *constant of integration* and represent an arbitrary vertical translation of all the functions, also called *antiderivatives*, that can be differentiated to obtain the integrand function. When the integral is expressed over an interval $[a, b]$, it is also called a definite integral and it is written as:

$$\int_a^b f(x)\,dx$$

In general, the integral is used to calculate areas and volumes. A definite integral over an interval $[a, b]$ represents the area of the plane that is delimited by the graph of the considered integrand function and is calculated between the two endpoints of the specified interval. For instance, Figure 1 represents $\int_0^2 -x + 3\,dx$, that is the area delimited by the function $f(x) = -x + 3$ over the $[0, 2]$ interval.

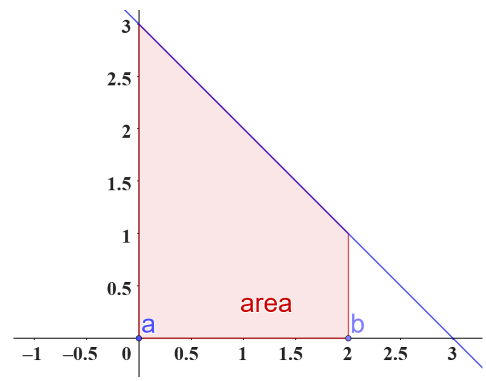


Fig. 1: Definite integral of a function over the $[0, 2]$ interval.

Usually, at least in Italian education, integrals are considered a brief (and, sometimes, optional) addendum that is often delivered at the end of a few, selected secondary education curricula. Lessons often consists of theoretical explanations followed by on-paper exercises, but in the limited time available teachers may fail to communicate all the notions needed to fully master the topics, with the result that students can often find the study of integrals difficult and alienating.

B. Escape Rooms

An Escape Room is a game where one or more players are inserted into a gaming environment, with the final aim of exiting the room. This usually happens by solving a series of enigmas or mini-games that can be interdependent, i.e., solving an enigma can provide an assist for the other ones. Assists can come in different shapes, e.g., an enigma can provide an object or a piece of information that can or must be used later in the room. The path to exit a room can be either linear (all the enigmas and mini-games must be solved in sequence), open (enigmas and mini-games can be solved in any order), or multi-linear (a combination of the two paths, where certain enigmas and puzzle bust be solved in sequence, and other can be solved independently) [21].

Inside the environment, enigmas and mini-games usually consist of simple challenges that can be solved by moving a series of objects, activating buttons, or inserting codes. Challenges can be either physical, focused on manipulation, or mental, requiring logic and reasoning. The difficulty of the challenges is usually not elevated, and the overall difficulty of the Escape Room is associated with the number of challenges and how they interact with each others.

Finally, one of the key aspects of Escape Rooms is the underlying narrative. A narrative can be considered solid when it ties together all the enigmas and mini-games and frames them in a coherent structure, also giving diegetic hints for their solution when the path is linear. Moreover, a solid narrative enhances the feeling of presence, helps the users in keeping their attention high, and can be associated with elevated levels of engagement.

III. Methodology

This section describes the implementation, the features, the mini-games and the narrative of the devised immersive application, along with the tackle mathematics topics and concepts.

A. Technology

The devised Escape Room was developed using Unity as a standalone VR application for VR head-mounted displays, specifically the Meta Quest 1, 2, 3 and Pro. The VR component was managed using the XR Interaction Toolkit, and all interactions were designed to be controller-based. All the 3D objects were created using Blender.

B. The Application

The devised application was designed as a VR Escape Room where players (students, in particular) can study the concept of integral an exercise to improve their skills. The experience takes place in three different environments: the student's bedroom, an dream-like version of the same bedroom, and a ship.

The experience starts with a brief tutorial on the VR interface, focused on the interaction and locomotion methods. Afterwards, the player takes the role of an insecure student, inside his or her bedroom, who goes to bed the night before a mathematics test focused on integrals. During the night, the student wakes up in a dream-like scenario, an alternative version of the bedroom where several objects (a bookcase, an electrical switchboard, a piano, and a projector) have been altered. To bring the objects to their original form, the student is then tasked to solve a series of challenges (namely, mini-games that target several aspects of the concept of integral) to escape the room.

Outside the room, the student finds himself or herself on a ship and, by solving a mini-game, he or she can discover that it is sailing towards Magna Graecia, the homeland of Archimedes and integrals. A storm is currently brewing and the ship is sinking, and the student shall solve other mini-games to build a simple raft and sail to safety.

Finally, the student wakes up in his or her bedroom and realizes it was all a dream; however, the experience helped him or her to study and exercise, thus building up his or her confidence and making him or her ready for the integrals test.

During the experience, the player is guided by two voices: a first one that introduces the scenario and the basic functionalities needed to navigate the virtual world (e.g., the teleport-based locomotion system), and a second one that represents the player's inner monologue and can be heard throughout the whole experience. This second voice is crucial to guide the player and gives hints on the several challenges.

C. The Challenges

In order to finish the experience and exit the VR Escape Room, players need to solve a total of seven challenges that are organized in a linear path. The first four challenges focus on indefinite integrals and are located in the second virtual environment (the dream-like bedroom), the other three focus on definite integrals and solids of revolutions and are located in the third environment (the ship). In detail, the challenges are the following:

- *Challenge 1:* the electrical switchboard (integration and differentiation). In this challenge, the player is asked to use a series of cables to make connections on an electrical switchboard in order to turn on the light. Each cable must be connected to two exposed contacts on the switchboard, and each contact corresponds either to a indefinite integral or to an antideritvative (Fig. 2); a correct connection links an indefinite integrals to the corresponding antiderivative. Once all the cables are correctly connected, the light will turn on and the player will be directed to the second challenge.

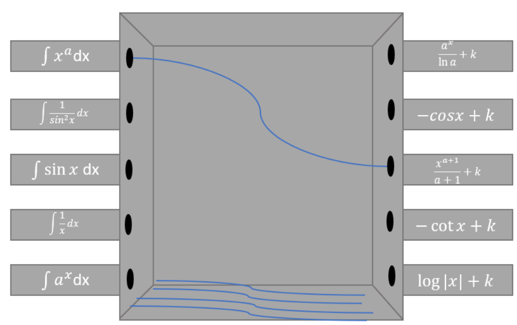


Fig. 2: A scheme of the first challenge. Each indefinite integral must be connected to the correct antiderivative.

- *Challenge 2:* the bookcase (integrand function and antiderivative). In this challenge, the player is asked to put a series of books in order, trying to arrange them in such a way that the images on their spines compose the graph of an antidertivative of a given function. Several books are available, but only a given subset should be used to solve this challenge. Once the challenge is solved, a bookcase drawer will open, revealing items (i.e., tiles of several colors, representing mathematical formulas and expressions) that can be used in the next challenge 3.
- *Challenge 3*: the projector (integration by substitution). In this challenge, the player finds him or herself in front

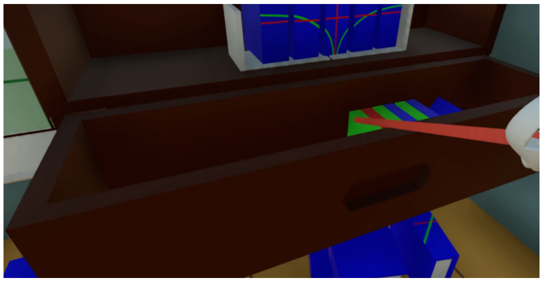
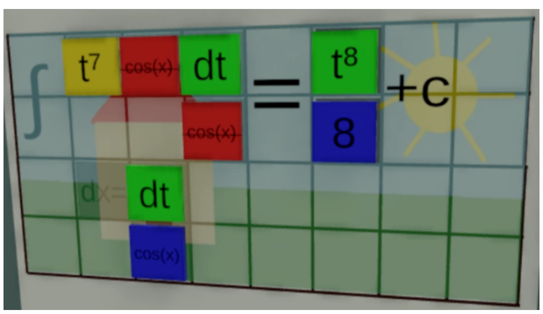
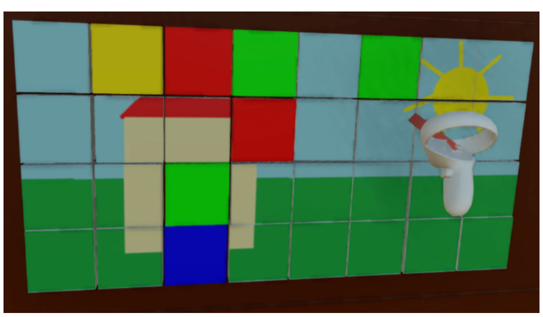


Fig. 3: Once the second challenge is completed, the drawer opens to reveal items useful for the next challenge.

of an image of a house that is projected on the wall. An indefinite integral is over imposed on the image, and the player is asked to use the colored tiles collected in the previous challenge to perform the required substitutions needed to simplify the integral. Once all the correct tiles are used, they define a colored pattern on the image, representing the solution to this challenge (Fig. 4a).
The player is then directed towards a picture framed on another wall, depicting the same image as before. By replicating the same colored pattern on this picture (Fig. 4b), the player opens a secret compartment, revealing an item (a music sheet) that can be used in the next challenge.



(a)



(b)

Fig. 4: In the third challenge, (a) the player simplify an integral expression by substitution, thus defining (b) a pattern that can be used to proceed with the experience.

- *Challenge 4*: the piano (integration by parts). In this challenge, the player is asked to use the music sheet collected in the previous challenge to play a melody on the piano. The music sheet contains an indefinite integral, and each key of the piano corresponds to a specific formula or concept that can be used to solve the integral. If the player chooses the correct keys, the piano plays in tune, otherwise the piano is out of tune and the player must go back to the beginning and repeat the melody. Once the melody is completed, the bedroom door unlocks and the player is free to move to the next environment.
- *Challenge 5*: the hull of the ship (definite integral). In this challenge, the player is asked to repair a hole in the hull of the ship using wooden planks. The hole corresponds to the positive area delimited by the graph of an integrand function, and the player can use planks of various width to approximate the area. If the player uses wide planks, he or she can quickly repair the hole but the final result corresponds to a coarse approximation of the considered area; by using thinner planks, instead, it is possible to achieve a finer and more accurate approximation of the area, but the process takes more time.
- *Challenge 6*: the map (mean value theorem). In this challenge, the player is asked to interact with two elements on a map (called *a* and *b*) in order to find a point P with coordinates (c, f(c)), representing a secret compartment containing an useful item that will be required in Challenge 7. The two elements on the map represents the two endpoints of a definite integral, and their relation to the point P is determined by the mean value theorem:

$$\frac{\int_a^b f(x)\,dx}{b-a} = f(c)$$

- *Challenge 7*: the barrel (solids of revolutions). In this challenge, a storm is brewing and the player is asked to use the item collected in the previous challenge (the prototype of a barre) to abandon the ship and get to safety. The player, using the prototype as reference, needs to select a integrand function that accurately replicate the profile of the barrel, choose two endpoints to define the boundaries of the revolution, and then manually rotate the profile to obtain the barrel.

D. Exercises and Evaluation

In order to use the devised VR Escape Room as a pedagogical tool to exercise on the concept of integrals (and, potentially, as a tool to perform interrogations and evaluate students), two considerations have been made during the design phase of the experience, also thanks to the help of secondary education teachers that collaborated with the authors.

Firstly, it was deemed necessary to add an evaluation module to track the players' actions during the experience. Specifically, this module keeps track of the time required to complete each challenge, and the number of mistakes made for each challenge. Using this information, it is possible to determine the players' shortcomings, and whether the challenges have been overcome satisfactorily or through a brute-force approach.

Secondly, to make the devised Escape Room reusable, it was deemed necessary to add the possibility to customize the experience by adding a database of exercises that can be used to change the parameters of each challenge. By using this feature, even though the main topic of each challenge remains the same, the functions, parameters and solutions can be altered. Therefore, the VR Escape Room can be easily used multiple times with the same player, without risking that he or she proceeds by heart and without reasoning.

IV. EXPERIMENTS

Two experiments were conducted to evaluate the devised VR Escape Room. The first one consisted of a pilot study aimed at evaluating the usability of the devised system and collecting feedback to improve the application; the second one consisted of a user study and was conducted in order to evaluate the usability, the quality and the learning gain associated with the use of the devised VR Escape Room.

A. Sample

The pilot study involved 12 participants (eight males and four females) aged between 25 and 29 years ($M = 26.33$, $SD = 1.60$). These participants were fellow researchers with previous experience with immersive technologies. The second study involved nine participants (five males and four females) aged between 18 and 19 ($M = 18.08$, $SD = 0.28$), corresponding to a fifth year class of the High School "25 Aprile - Faccio", Cuorgnè (TO).

B. Procedure and tools

For what it concerns the pilot study, all participants were asked to experience the devised VR Escape Room and then were administered the System Usability Scale (SUS) questionnaire [22], consisting of 10 questions to be evaluated on a 1-to-5 Likert scale and investigating various aspects of the devised application's usability.

Moving to the second study, a test covering various aspects of integrals was administered before the experience to evaluate the participants' knowledge on the topic. This test, composed of seven questions, was designed with the help of a Mathematics teacher to be similar to a traditional, in-class test that would be normally administered to students. The exercises in this test were also similar to the challenges in the devised application, although the considered functions and parameters were different. It is important to highlight that no feedback on the test was given to the students, during the experience. After this test was completed, the participants were asked to experience the devised VR Escape Room, and the results of the corresponding evaluation module were recorded.

Finally, the participants of the second study were asked to fill in a subjective questionnaire, composed of:

- the SUS questionnaire, evaluating the usability of the application.
- a subset of the categories of the AttrakDiff questionnaire [23] evaluating only the Attractiveness and Hedonic Quality Stimulation of the devised learning experience, as previously did by Jost et al. [24]. Specifically, participants were asked to rate 14 pairs of terms on a 1-to-7 Likert scale.

C. Results

The results of the pilot study showed an overall appreciation for the devised application; specifically, looking at the total score of the SUS questionnaire, the usability of the devised application was rated positively ($M = 86.67$, $SD = 11.56$). Feedback from this study were used to slightly improve the user experience, with minor adjustments to the interaction and locomotion interfaces and to some challenges.

As for the second study, and starting from the subjective measures, the SUS questionnaire highlighted again a positive evaluation of the application usability ($M = 83.61$, $SD = 10.15$). No significant differences between these evaluation and the one conducted in the previous study ($p = .549$) were found. Moreover, looking at the results of the AttrakDiff questionnaire (Fig. 5), all items were scored below two, corresponding to a positive evaluation of the considered categories.

Finally, moving to the objective measures, on the one hand the test was evaluated on a 0-to-7 scale, assigning one point to each correct answer and zero otherwise. On the other end, the assessment provided by the evaluation module was considered only if a challenge was solved in a limited time, and with no mistakes. A point was assigned to each challenge solved within these criteria. By confronting the outcomes of these assessments, a significant difference was highlighted ($M = 1.55$, $SD = 0.83$ for the test, $M = 4.37$, $SD = 0.81$ for the evaluation module, $p \leq .001$).

V. CONCLUSIONS

This paper presents a VR Escape Room designed to help players (and, specifically, high school students) in the study of integrals. The devised application aims to overcome the limitations of traditional teaching methods (frontal lessons and on-paper exercises), that seldom fail to engage students, by leveraging gamification to offer a gaming experience inspired by Escape Rooms. By replacing the exercises with challenges that are tied together by a overarching narrative, the resulting learning experience should be able to stimulate the players' reasoning, making them more focused on the considered topics and prompting them to solve each challenge to move further in the experience.

In order to evaluate the effectiveness of the devised application, two studies were conducted. The first one was a pilot study to assess its usability, involving fellow researchers. Results showed that the overall usability of the system was considered positive, and the collected feedback was used to implement a series of minor adjustments to improve the quality of the user experience. The second study, using the improved version of the application, involved high school students and investigated if the use of the VR Escape Room could be associated with a positive impact on the students' learning. Indeed, the outcomes of this second study showed that, by using the application, students were able to solve more

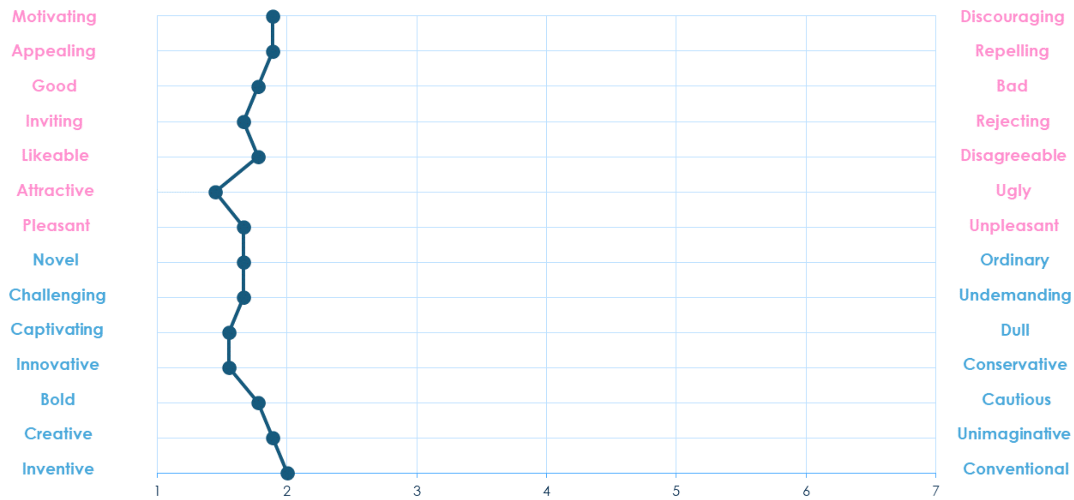


Fig. 5: Results of the AttrakDiff questionnaire for the two considered categories (Attractiveness and Hedonic Quality Stimulation).

exercises on the considered topic and a significant learning gain was highlighted.

Moving to the limitations of this work, the first one could be identified with the fact that, in devised Escape Room, the challenges were organized on a linear path. Although this design choice was made to reflect the traditional learning path that is followed to learn integrals (as seen, for instance, in the considered book [20]), it is possible that, by arranging the content in a different way and designing certain challenges to be independent, the resulting multi-linear experience could lead to different results in terms of overall appreciation and learning gain. A second limitation could be identified in the number of participants involved in the studies, and in particular in the second one. Although the nine students corresponded to the target users for the devised application, and represented an entire class from the considered high school, further investigations involving a larger sample are needed. Future research directions will focus on addressing the above limitations, and further improving the devised system to include other scenarios and topics.

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References

[1] J. Chatain, V. Ramp, V. Gashaj, V. Fayolle, M. Kapur, R. W. Sumner, and S. Magnenat, “Grasping derivatives: Teaching mathematics through embodied interactions using tablets and virtual reality,” in *Proceedings of the 21st Annual ACM Interaction Design and Children Conference*, ser. IDC ’22. Association for Computing Machinery, 2022, p. 98–108.

[2] L. Bian, “Application of digital technology in open and distance education,” in *2009 International Conference on Networking and Digital Society*, vol. 1, 2009, pp. 273–276.

[3] A. Delgado, L. Wardlow, K. O’Malley, and K. McKnight, “Educational technology: A review of the integration, resources, and effectiveness of technology in K-12 classrooms,” *Journal of Information Technology Education: Research*, vol. 14, p. 397, 2015.

[4] M. Muktiarni, N. I. Rahayu, A. Suwandi, S. Rahayu, A. Ismail, and J. Mupita, “Shifting to digital education: An analysis of teacher knowledge and its implementation of open educational resources in vocational schools,” *Journal of Advanced Research in Applied Sciences and Engineering Technology*, vol. 45, no. 2, p. 240 – 257, 2025.

[5] R. Raja and P. Nagasubramani, “Impact of modern technology in education,” *Journal of Applied and Advanced Research*, vol. 3, no. 1, pp. 33–35, 2018.

[6] A. Cannavò, F. De Lorenzis, F. Lamberti, and C. Demartini, “A systematic literature review of learning assessment material authoring systems,” in *EDULEARN22 Proceedings*, ser. 14th International Conference on Education and New Learning Technologies. IATED, 2022, pp. 5334–5344.

[7] L. Zeng and L. Cai, “Innovative design of music education mode based on internet technology,” in *2021 International Symposium on Advances in Informatics, Electronics and Education (ISAIEE)*, 2021, pp. 208–211.

[8] X. Liu, Y. Chi, G. Wei, and T. Wu, “The research of modern educational technology application in architecture,” in *2009 First International Workshop on Education Technology and Computer Science*, vol. 2, 2009, pp. 72–75.

[9] I. Kilic, D. Goren, D. Ozturk, and D. Guven, “The learning environment design of an energy system model for middle school science,” *International Journal of Science, Mathematics and Technology Learning*, vol. 32, no. 1, p. 83 – 105, 2025.

[10] M. Noor Kholid, A. Hendriyanto, S. Sahara, L. H. Muhaimin, D. Juandi, I. Sujadi, K. Singgih Kuncoro, and M. Adnan, “A systematic literature review of technological, pedagogical and content knowledge (tpack) in mathematics education: Future challenges for educational practice and research,” *Cogent Education*, vol. 10, no. 2, p. 2269047, 2023.

[11] A. Cannavò, F. D. Lorenzis, F. G. Pratticò, L. Galante, and F. Lamberti, “On the quality of the experience with virtual reality-based instructional tools for science lab activities,” *Journal of Educational Computing Research*, 2024.

[12] U. Hanifah, I. K. Budayasa, and R. Sulaiman, “Technology, pedagogy, and content knowledge in mathematics education: a systematic literature

review," *Journal of Education and Learning (EduLearn)*, vol. 19, no. 1, 2025.

[13] D. Bhatia and H. Hesse, "Enhancing student engagement in engineering and education through virtual reality: A survey-based analysis," in *TENCON 2023 - 2023 IEEE Region 10 Conference (TENCON)*, 2023, pp. 170–175.

[14] Y.-S. Su, C.-F. Lai, and C.-F. Lai, "Study of virtual reality immersive technology enhanced mathematics geometry learning," *Frontiers in psychology*, vol. 13, p. 760418, 2022.

[15] Y.-C. Hsu, "Exploring the learning motivation and effectiveness of applying virtual reality to high school mathematics," *Universal Journal of Educational Research*, vol. 8, pp. 438–444, 02 2020.

[16] S. Arnab, T. Lim, M. B. Carvalho, F. Bellotti, S. De Freitas, S. Louchart, N. Suttie, R. Berta, and A. De Gloria, "Mapping learning and game mechanics for serious games analysis," *British J. of Educational Technology*, vol. 46, no. 2, pp. 391–411, 2015.

[17] S. Tang, M. Hanneghan, and A. El-Rhalibi, "Pedagogy elements, components and structures for serious games authoring environment," in *5th Int. Game Design and Technology Workshop (GDTW 2007), Liverpool, UK*, 2007, pp. 26–34.

[18] Y. A. Rankin, R. Gold, and B. Gooch, "Playing for keeps: gaming as a language learning tool," in *ACM SIGGRAPH 2006 Educators program*. ACM, 2006, p. 44.

[19] A. Visconti, M. Nadalin, F. De Lorenzis, F. G. Pratticò, and F. Lamberti, "Integrating the time travel mechanic in vr serious games to enhance causal reasoning," in *2024 IEEE Gaming, Entertainment, and Media Conference (GEM)*, 2024, pp. 1–6.

[20] M. Bergamini, G. Barozzi, and A. Trifone, *Matematica.verde*. Zanichelli, 2016, vol. 3.

[21] M. Wiemker, E. Elumir, and A. Clare, *Escape Room Games: "Can you transform an unpleasant situation into a pleasant one?"*, 2015, pp. 55–75.

[22] J. Brooke, *"SUS-A quick and dirty usability scale." Usability evaluation in industry*. CRC Press, 1996.

[23] M. Hassenzahl, F. Koller, and M. Burmester, "Der user experience (UX) auf der spur: Zum einsatz von www.attrakdiff.de," in *Tagungsband UP08*, H. Brau, S. Diefenbach, M. Hassenzahl, F. Koller, M. Peissner, and K. Röse, Eds. Stuttgart: Fraunhofer Verlag, 2008, pp. 78–82.

[24] P. Jost, S. Cobb, and I. Hämmerle, "Reality-based interaction affecting mental workload in virtual reality mental arithmetic training," *Behaviour & Information Technology*, vol. 39, no. 10, pp. 1062–1078, 2020.