Virtual Immersion in STEM Education: A MICMAC Study on How Virtual Reality Impacts the Understanding and Application of Scientific Concepts

Piedad Mary Martelo Gómez[1], Raúl José Martelo Gómez[2], David Antonio Franco Borré[3]

[1]Odontologist. Independent researcher. Professor of the Dentistry Program at the Universidad de Cartagena, Colombia. Email: pmartelog@hotmail.com.
[2]Specialist in Networks and Telecommunications; Master in Computer Science. Systems Engineer. Full-time Research Professor of the Systems Engineering Program at the Universidad de Cartagena. Leader of the INGESINFO Research Group. Cartagena de Indias, Colombia. E-mail: rmartelog1@unicartagena.edu.co
[3]Master in Computer Science. Systems Engineer. Full-time Research Professor of the Systems Engineering Program at the Universidad de Cartagena. Cartagena Colombia. E-mail: dfrancob@unicartagena.edu.co.

Abstract

The integration of virtual reality into STEM education has generated growing interest in how this technology impacts the understanding and application of scientific concepts. This study focuses on investigating this relationship by using the MICMAC technique to identify key variables and their interactions in virtual educational environments. It was found that variables such as the design of educational content, the quality of the virtual experience, and the interactivity of the environment are key to the learning process in STEM. In addition, determinant and autonomous variables were identified, which play fundamental roles in the generation of scientific knowledge for students. These results highlight the relevance of considering various aspects of virtual educational design to improve the effectiveness of learning in STEM. The practical implications of this study are significant for educators and educational program designers, highlighting the need to create immersive, interactive, and collaborative virtual environments to promote better understanding and application of scientific concepts. This study contributes to existing knowledge by providing a deeper understanding of how virtual reality can enhance learning in STEM, and suggests directions for future research in the field.

Keywords: technology, user experience, collaborative learning, formative evaluation, digital skills.

1. Introduction

The linking of technology to education has revolutionized the way STEM (Science, Technology, Engineering, and Mathematics) disciplines are taught and learned. Among the most promising educational technologies is virtual reality (VR), which offers an immersive environment and interactive experiences that can significantly improve the understanding and application of scientific concepts among students (Liu, et al., 2020). This study focuses on exploring the impact of VR on STEM education, with a specific focus on the understanding and application of scientific concepts. It is investigated how virtual immersion in educational environments can influence the learning process (LP), from the acquisition of knowledge to its application in practical contexts.

Previous research has demonstrated the ability of VR to improve STEM education (Pellas, et al., 2020). Studies have highlighted its benefits in terms of increasing students' motivation (Sattar, et al., 2020), improving information retention (Makransky & Mayer, 2022), and promoting the understanding of abstract concepts (Chen, et al., 2020). However, a deeper understanding of the variables that impact the effectiveness of VR in STEM education, as well as their interactions and relationships, is necessary. The present study is relevant in the current field of education, where technology plays an increasingly relevant role in the teaching-learning process.

Understanding how VR can improve the understanding and application of scientific concepts is crucial to inform the design of effective educational interventions and promote the development of STEM skills among students. Therefore, the purpose of this study was to investigate how VR impacts the understanding and application of scientific concepts in STEM education. For this purpose, the MICMAC technique was applied to identify the relevant variables in this context and analyze their influence and dependence on each other. Through this analysis, a more complete understanding of the factors that contribute to the success of VR implementation in STEM education is provided.

This study is organized into several sections. First, the methodology used to carry out the study will be detailed, including the application of the MICMAC technique. Subsequently, the discussions and results obtained are presented, followed by conclusions and recommendations for future research.

2. Methodology

This study is framed within qualitative research with a mainly theoretical-conceptual approach because the main objective is to understand in depth the interactions and relationships between the relevant variables in the context of VR in STEM education. A qualitative approach will provide a rich and detailed understanding of the processes involved (Nassaji, 2020). The selected design was exploratory because the objective is to investigate a relatively little-explored phenomenon, such as the impact of VR on STEM education, an exploratory approach allows a detailed and systematic exploration of the relevant variables and their interactions (Swedberg, 2020). This design will provide a solid foundation for future research and can help generate hypotheses for further research.

The MICMAC technique (Multiplicative Cross Impact Matrix Applied to a Classification) was used to analyze the influence and dependence between the relevant variables identified in the field of virtual immersion in STEM education. A matrix was constructed in which the identified variables were placed in rows and columns. Then, the relationship between each pair of variables was evaluated and the influence was classified as high, medium, or low, depending on the degree of impact of each variable. This allowed to determine the variables that have a significant impact on the understanding and application of scientific concepts in the context of VR in STEM education. After completing the MICMAC analysis, the results obtained were interpreted.

The variables with the greatest impact on the understanding and application of scientific concepts in STEM education through VR were identified, and special attention was paid to those variables that act as main drivers and those that are most susceptible to the influence of other variables. It was examined how these variables interact with each other and how these relationships can affect the success of implementing VR in STEM education.

3. Results

The relevant variables identified in the field of VR applied to STEM education are analyzed, using the MICMAC technique to explore their influence and dependence. The results are presented in a structured manner and discussed based on the research objectives and existing literature.

The first outcome consisted of a list of the top ten (10) variables identified through a review of the literature on virtual immersion in STEM Education. These variables are shown in Table 1 below. In this table, the header includes the number, code, name, and description of each variable. For example, in the first row, variable number 1 is identified with the QVE code and is called "Quality of the Virtual Experience", with the following description: "It is critical to assess the overall quality of the virtual experience, as it significantly affects learners' participation and learning in the virtual environment”. In this way, the list of variables is displayed in Table 1.

Table 1. Variables Related to Virtual Immersion in STEM Education

#	Code	Variable	Description
1	QEV	Quality of the virtual experience	It is critical to assess the overall quality of the virtual experience, as it significantly affects learners' participation and learning in the virtual environment.
2	ECD	Educational content design	Educational content design is essential to ensure that scientific concepts are presented in a clear, attractive and relevant way for educational objectives.
3	IVE	Interactivity of the virtual environment	Interactivity allows learners to actively participate in the LP, explore scientific concepts and experiment with different virtual scenarios.
4	SM	Student motivation	Motivation is crucial for students' engagement and persistence in learning, so it is important to evaluate how VR can influence learners' intrinsic motivation.

5	USC	Understanding of scientific concepts	Assessing understanding of scientific concepts is critical to determining whether VR facilitates or hinders knowledge acquisition in the STEM field.
6	ASC	Application of scientific concepts	Learners' ability to employ scientific concepts in practical situations is an important indicator of learning success, so it is crucial to evaluate how VR facilitates this knowledge transfer.
7	SF	System feedback	System feedback can influence learners' learning by providing guidance and feedback on their performance, which can improve the effectiveness of the virtual educational experience.
8	DI	Data interpretation	The ability to interpret scientific data is a critical skill in STEM, so it is important to evaluate how VR can support the development of this competency in learners.
9	CBS	Collaboration between students	Collaboration between students can foster collaborative learning and the exchange of ideas in the virtual environment, which can enrich the educational experience and improve understanding of scientific concepts.
10	IDC	Inclusion of diversity of content	Ensuring that virtual educational content is diverse and representative of different areas of study in STEM is important to address the needs and interests of a wide range of students.

Source: Authors

The next step consisted of involving 5 experts in STEM education in a collective reflection to evaluate the influence and dependence relationships of each variable in a square matrix, corresponding to Phase II of the MICMAC technique. Figure 1 shows the matrix that represents direct influence and dependence, which was completed through consensus and joint reflection of the experts. It is important to note that the first row of the matrix reflects the influence relationships of the variable "Quality of the virtual experience" (QVE). In this sense, the relationship with this same variable is null (0), the relationship with the variable "Educational content design" (ECD) is rated as strong (3), as is the relationship with the variable "Interactivity of the virtual environment "(IVE) is considered strong (3). In this way, the direct influence relationship between each variable is detailed.

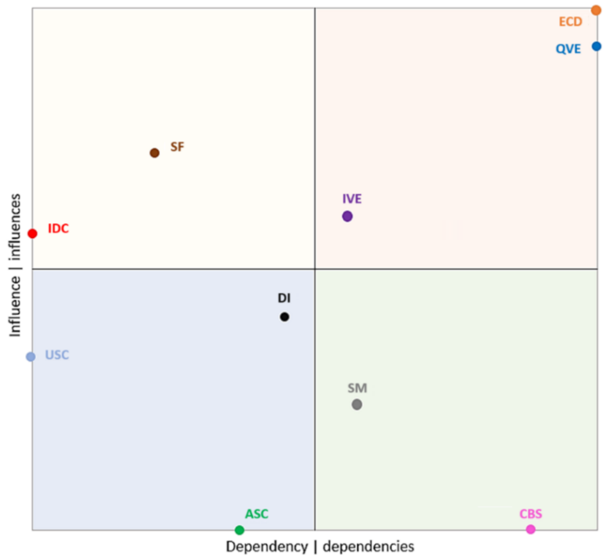
Figure 1. Matrix of direct influence/dependency

Influence ↱	QVE	ECD	IVE	SM	USC	ASC	SF	DI	CBS	IDC
QVE	0	3	3	3	3	3	3	2	3	2
ECD	3	0	3	3	3	3	1	2	3	3
IVE	3	3	0	1	2	2	3	1	3	0
SM	2	1	0	0	1	2	1	2	1	1
USC	2	2	1	2	0	3	0	1	1	0
ASC	1	2	1	0	0	0	0	1	2	0
SF	3	3	3	2	0	0	0	3	3	3
DI	1	3	1	2	1	1	2	0	2	1
CBS	3	1	1	0	0	0	2	0	0	0
IDC	3	3	3	3	0	0	0	3	2	0

Source: authors

Once the relationships were established in the matrix of direct influence/dependence, the next step involved the categorization of the variables. This classification is reflected in a plane that represents direct influence and dependence, illustrated in Figure 2. As a result of this analysis, three variables have been identified in the key variables quadrant: ECD, QVE, and IVE. Two variables have been located in the quadrant of the determinant variables: SF and IDC. On the other hand, three variables were located in the autonomous variables quadrant: DI, USC, and ASC. Finally, the SM and CBS variables were placed in the quadrant of the result variables.

Figure 2. Plane of direct influence/dependency



Source: Authors

Table 2 better explains the results obtained.

Table 2. Classification of factors by direct influences/dependencies

Type of Variable	Variable	Code
Key, strategic or challenge variables	Educational content design	ECD
	Quality of the virtual experience	QVE
	Interactivity of the virtual environment	IVE
Determinant or "influencing" variables	System feedback	SF
	Inclusion of diversity of content	IDC
Autonomous or independent variables	Data interpretation	DI
	Understanding of scientific concepts	USC
	Application of scientific concepts	ASC
Dependent or result variables	Student motivation	SM
	Collaboration between students	CBS

Source: Authors

As seen in the table, three variables were classified as key, which means that these variables have a high influence and a high dependency, which is why they are the challenge variables. In the case of the variable ECD (Educational content design), it was classified as a key variable due to the impact it has on other variables. According to Marougkas, et al. (2023), educational content design has a direct impact on the way scientific concepts are presented and organized within the virtual environment. So an effective design can facilitate students' understanding and their ability to apply concepts in practical situations, while a poor design can hinder learning.

On the other hand, Saiyad, et al. (2020) state that educational content must be relevant and aligned with specific learning objectives. Furthermore, Coman, et al., (2020) point out that the sequence and structure of educational content can impact the way in which learners process information and construct their understanding. In this sense, a well-structured design can guide students through concepts in a logical and coherent manner, facilitating the assimilation and retention of information. Likewise, educational content design can incorporate interactive elements and learning activities that maintain the interest and engagement of learners, which can include simulations, practical exercises, and opportunities to explore and experiment within the virtual environment.

Regarding the classification of QEV (Quality of the virtual experience) as a key variable, it is due to the fact that it directly affects the experience of students and their ability to interact and learn in virtual environments. This classification suggests that its impact on the LP is significant and may present challenges in terms of its effective implementation and maintenance over time. According to Servotte, et al. (2020), the quality of the virtual experience influences the degree of immersion that students experience within the virtual environment, so a high-quality experience could increase the commitment and participation of learners, which in turn improves the LP.

According to Tsivitanidou, et al. (2021), a high-quality virtual experience is characterized by its realism and authenticity, allowing students to feel completely immersed in the virtual environment, facilitating suspension of disbelief and emotional connection with the concepts and situations presented. While Su, et al. (2020) express that the quality of the virtual experience is also reflected in the usability of the virtual environment and the ease with which students can navigate and explore the content. A well-designed, intuitive interface makes information easy to access and reduces barriers to learning.

Finally, the classification of the variable IVE (Interactivity of the virtual environment) is due to the fact that it significantly influences the commitment, exploration, and feedback of the students. Its classification as a key variable suggests that its effective implementation may be essential for the success of the LP in virtual environments and may require a special approach in terms of design and development. According to Luo, et al. (2022), the interactivity of the virtual environment plays a crucial role in student engagement, so a highly interactive virtual environment can maintain students' attention for longer periods, and boost their active participation in the LP.

According to Liu, et al. (2020), interactivity allows learners to explore and experiment with scientific concepts practically and safely within the virtual environment. This gives them the opportunity to learn through direct experimentation and discovery, which can improve their understanding and retention of information. While Alamri, et al. (2021) state that the interactivity of the virtual environment can adapt to the individual needs of learners, providing personalized learning options and allowing students to progress at their own pace. This can improve learning effectiveness by addressing individual differences in learning styles and proficiency levels.

On the other hand, an interactive virtual environment can provide immediate feedback to students on their performance and progress, allowing them to correct errors and improve their understanding in real-time. Additionally, instant feedback can improve learning effectiveness by providing timely and relevant guidance. Likewise, the interactivity of the virtual environment can encourage problem solving and critical thinking by challenging learners with complex scenarios and allowing them to make decisions and face the consequences of their actions within the virtual environment.

The three key variables above could impact the understanding and application of scientific concepts in the field of virtual STEM education in the following ways: in terms of the Quality of the virtual experience, greater understanding, improved retention, and practical applications. In reference to the Interactivity of the virtual environment, active learning, Immediate feedback, and the development of skills. While, regarding Educational content design, it impacts clarity and relevance, logical organization and adaptability, and personalization. Together, these three key variables interact to create an effective virtual learning environment that improves the understanding and application of scientific concepts in STEM education.

Regarding the variables that were classified as determinants, in the case of the variable SF (System feedback) it was classified as such because it provides guidance, error correction, positive reinforcement, and personalization of learning. Its classification as a highly influential variable suggests that its effective implementation is essential to optimize the LP and improve the understanding and application of scientific concepts in STEM education.

According to Bortone, et al. (2020), system feedback provides guidance to students during their interactions in the virtual environment. This feedback helps them understand how they are progressing and what actions they can take to improve their learning. Likewise, they state that the feedback system allows learners to detect and correct errors immediately. This helps them learn actively and avoid internalizing incorrect concepts. While Lohmann, et al. (2021) state that in addition to correcting errors, system feedback can offer positive reinforcement when students make correct decisions or complete tasks successfully, which motivates students and reinforces their confidence in their ability to apply scientific concepts.

On the other hand, system feedback can be adapted to the individual needs of learners, providing specific and relevant feedback according to their progress and performance. This personalization increases learning effectiveness by addressing individual differences in learning styles and proficiency levels. Likewise, this variable promotes reflective learning by encouraging learners to review and reflect on their performance. This helps them develop metacognition and better understand their own learning processes.

In reference to IDC (Inclusion of diversity of content), it was classified as a determinant variable because it guarantees the representativeness, relevance, and relevance of the content for a diverse audience of students. Its classification as a highly influential variable suggests that its effective implementation is essential to optimize the LP and improve the understanding and application of scientific concepts in STEM education. According to Pellas, et al. (2020), the inclusion of a wide diversity of content in the virtual environment more accurately reflects reality and the various areas of study in STEM. This allows learners to experience a wider range of situations and practical applications of scientific concepts, which improves their understanding and appreciation of the topic.

For Caro, et al. (2023), including a variety of content that spans different disciplines and perspectives in STEM ensures that the virtual environment is relevant to a diverse audience of students. This increases learners' participation and engagement by presenting them with topics that are relevant to their individual interests and experiences. While for Barzilai & Chinn (2020), exposure to a variety of content challenges learners to evaluate information from multiple perspectives, which promotes critical thinking and learners' ability to solve complex problems when facing a diversity of challenges and scenarios in the virtual environment. Diversity of content can also include representation of different cultures, ethnicities, and genders.

The variable DI (Data interpretation) was classified as autonomous due to its fundamental importance and its ability to function independently in the LP in virtual environments. Its classification as autonomous suggests that this skill is crucial for success in STEM and should receive specific attention and emphasis in the design and development of virtual educational environments. According to Hafni, et al. (2020), data interpretation is a fundamental skill in the STEM field, which encompasses disciplines such as science, technology, engineering, and mathematics. This skill is essential to analyze and understand experimental results, scientific models, and quantitative data in general.

For Lindgren, et al. (2020), data interpretation is relevant in a variety of contexts and situations, regardless of the specific content or topic of study. That is, students must be able to interpret data in various forms, such as graphs, tables, diagrams, and experimental results, to draw conclusions and make decisions. While for Faiqotuzzulfa & Putra (2022), data interpretation can be considered an independent skill that is not necessarily linked to other specific variables in the virtual environment. Although it may be related to the educational content and the interactivity of the environment, its importance and relevance transcend the limits of other variables and it can function autonomously in the LP.

Regarding the classification of the variable USC (Understanding of scientific concepts) as an autonomous variable, it is due to its fundamental importance and its ability to function independently in the LP in virtual environments. According to Sulai & Sulai (2020), the understanding of scientific concepts is essential in the context of STEM education, since it constitutes the basis on which knowledge and skills in science, technology, engineering, and mathematics are built. Therefore, this variable is essential for students to acquire a deep understanding of scientific principles and their application in different contexts.

On the other hand, Thahir, et al., (2020), state that the understanding of scientific concepts is usually one of the main objectives of learning in STEM educational environments because learners must be able to understand and explain theoretical and practical concepts, and relate them to each other to develop an integrated vision of science and its applications. The classification of this variable as autonomous is also due to the fact that this can be considered an autonomous skill that is not necessarily linked to other specific variables in the virtual environment and can be applied in a wide variety of situations. Students can use this understanding to address problems and challenges in everyday life, as well as in academic and professional contexts.

Finally, the variable ASC (Application of scientific concepts) was classified as autonomous due to its fundamental importance and its ability to function independently in the LP in virtual environments. According to Cheng & So (2020), applying scientific concepts implies learners' ability to use theoretical and practical knowledge in practical and real-world situations. This variable is essential to demonstrate the understanding and usefulness of scientific concepts in practical and applied contexts.

For Priemer, et al. (2020), this variable implies the development of practical competencies and problem-solving skills. In this sense, learners must be able to identify and select the appropriate scientific concepts to address a given situation and apply them effectively to solve problems. On the other hand, the ability to apply scientific concepts is an important criterion for evaluating students' learning in virtual environments because students must demonstrate their ability to use the knowledge acquired in practical and applied situations to evaluate their performance.

Continuing with the classification of the variables, the focus is on the result variables, of which two were classified. In the case of SM (Student motivation), it was classified as a result variable due to its significant influence on the general results of LP in virtual environments. Its ranking suggests that it is critical for the success of the LP and is positively related to academic performance. Therefore, it should be considered with special attention in the design and development of virtual educational environments. According to (Demir, 2020), student motivation has a direct impact on their commitment and participation in the LP. Which suggests that motivated students tend to be more engaged in educational tasks and actively participate in learning activities, which contributes to better academic performance.

For Filgona, et al. (2020), student motivation influences their level of persistence and effort dedicated to learning. That is, motivated students are more willing to overcome obstacles and persevere in achieving their educational goals, which can lead to deeper and more lasting learning. While for Fu, et al. (2020), student motivation can affect the quality of learning by influencing the depth of information processing and the amount of cognitive effort dedicated to educational tasks. Suggesting that motivated students tend to be more focused and engaged in learning, which can lead to deeper understanding and better retention of information.

Finally, the last variable classified as result was CBS (Collaboration between students), which was classified in this way, due to its significant influence on the general results of the LP in virtual environments. For Hodges (2020), collaboration between students encourages active learning by involving students in discussion activities, problem-solving, and collaborative projects. This active learning approach allows students to construct knowledge meaningfully and apply concepts learned in authentic contexts. On the other hand, collaboration between students provides opportunities for the development of important social skills, such as conflict resolution, teamwork, effective communication, and intercultural collaboration.

According to Zidny, et al. (2020), collaboration between students allows the integration of diverse perspectives, experiences, and knowledge in the LP. The above enriches the discussion and understanding of concepts by exposing students to different points of view and approaches to address problems. Likewise, this variable can lead to better academic performance by facilitating the exchange of ideas, joint problem-solving, and mutual support among classmates. Learners can benefit from the knowledge and skills of their peers, which can improve their understanding and mastery of concepts.

4. Conclusions

In this study, the impact of VR on STEM education was investigated, specifically focusing on how virtual immersion affects the understanding and application of scientific concepts. Clear objectives were established to explore the key variables that influence this process and the MICMAC technique was applied to identify the most relevant variables and their interaction in the virtual educational context.

The findings of this study revealed several significant conclusions. It was found that variables such as Quality of the virtual experience, Interactivity of the virtual environment, Inclusion of diversity of content, and Collaboration between students are determinants in the LP in virtual STEM education environments. In addition, autonomous variables such as Data interpretation, Understanding of scientific concepts, and Application of scientific concepts were identified, which play fundamental roles in the development of students' scientific knowledge and skills. The findings of this study are in line with existing literature that highlights the importance of content quality, interactivity, and collaboration in online learning.

The practical implications of this study are significant for educators, educational program designers, and professionals in the field of STEM education. The findings highlight the importance of designing virtual environments that are immersive, and interactive, and that encourage collaboration between students to improve the understanding and application of scientific concepts. On the other hand, this study contributes to existing knowledge by providing a deeper understanding of how VR can improve learning in STEM education. However, some limitations are recognized, such as the focus on a specific context and the need for additional research to further explore the interactions between the identified variables.

It is recommended that future research delve deeper into the interactions between the identified variables and explore how different design approaches can affect learning outcomes in virtual environments. Furthermore, it is suggested to investigate how VR can be adapted to meet the specific needs of diverse student groups and educational contexts. Finally, this study offers a comprehensive view of the role of VR in STEM education and highlights the importance of considering a variety of factors to improve students' learning experience.

WORKS CITED

Alamri, H., Watson, S., & Watson, W. (2021). Learning technology models that support personalization within blended learning environments in higher education. TechTrends, 65, 62-78.

Barzilai, S., & Chinn, C. (2020). A review of educational responses to the "post-truth" condition: Four lenses on "post-truth" problems. Educational Psychologist, 55(3), 107-119.

Bortone, I., Barsotti, M., Leonardis, D., Crecchi, A., Tozzini, A., Bonfiglio, L., & Frisoli, A. (2020). Immersive virtual environments and wearable haptic devices in rehabilitation of children with neuromotor impairments: a single-blind randomized controlled crossover pilot study. Journal of neuroengineering and rehabilitation, 17(1).

Caro, V., Carter, B., Millunchick, J., & Reeves, S. (2023). Teaching crystal structures in undergraduate courses: a systematic review from a disciplinary literacy perspective. Chemistry Education Research and Practice, 24(2), 394-406.

Chen, J., Huang, Y., Lin, K., Chang, Y., Lin, H., Lin, C., & Hsiao, H. (2020). Developing a hands-on activity using virtual reality to help students learn by doing. Journal of Computer Assisted Learning, 36(1), 46-60.

Cheng, Y., & So, W. (2020). Managing STEM learning: A typology and four models of integration. International Journal of Educational Management, 34(6), 1063-1078.

Coman, C., Țîru, L., Meseșan-Schmitz, L., Stanciu, C., & Bularca, M. (2020). Online teaching and learning in higher education during the coronavirus pandemic: Students' perspective. Sustainability, 12(24), 10367.

Demir, S. (2020). The role of self-efficacy in job satisfaction, organizational commitment, motivation and job involvement. Eurasian Journal of Educational Research, 20(85), 205-224.

Faiqotuzzulfa, F., & Putra, S. (2022). Virtual Reality's Impacts on Learning Results in 5.0 Education: a Meta-Analysis. International Transactions on Education Technology, 1(1), 10-18.

Filgona, J., Sakiyo, J., Gwany, D., & Okoronka, A. (2020). Motivation in learning. . Asian Journal of Education and social studies, 10(4), 16-37.

Fu, J., Lu, I., Chen, J., & Farn, C. (2020). Investigating consumers' online social shopping intention: An information processing perspective. International Journal of Information Management, 54, 102189.

Hafni, R., Herman, T., Nurlaelah, E., & Mustikasari, L. (2020). The importance of science, technology, engineering, and mathematics (STEM) education to enhance students' critical thinking skill in facing the industry 4.0. Journal of Physics: Conference Series.

Hodges, L. (2020). Student engagement in active learning classes. Active learning in college science: The case for evidence-based practice, 27-41.

Lindgren, B., Lundman, B., & Graneheim, U. (2020). Abstraction and interpretation during the qualitative content analysis process. International journal of nursing studies, 108, 103632.

Liu, R., Wang, L., Lei, J., Wang, Q., & Ren, Y. (2020). Effects of an immersive virtual reality-based classroom on students' learning performance in science lessons. British Journal of Educational Technology, 51(6), 2034-2049.

Lohmann, M., Randolph, K., & Oh, J. (2021). Classroom management strategies for Hyflex instruction: Setting students up for success in the hybrid environment. Early Childhood Education Journal, 49(5), 807-814.

Luo, N., Li, H., Zhao, L., Wu, Z., & Zhang, J. (2022). Promoting student engagement in online learning through harmonious classroom environment. The Asia-Pacific Education Researcher, 31(5), 541-551.

Makransky, G., & Mayer, R. (2022). Benefits of taking a virtual field trip in immersive virtual reality: Evidence for the immersion principle in multimedia learning. Educational Psychology Review, 34(3), 1771-1798.

Marougkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023). Virtual reality in education: a review of learning theories, approaches and methodologies for the last decade. Electronics, 12(13), 2832.

Nassaji, H. (2020). Good qualitative research. . Language Teaching Research, 24(4), 427-431.

Pellas, N., Dengel, A., & Christopoulos, A. (2020). A scoping review of immersive virtual reality in STEM education. IEEE Transactions on Learning Technologies, 13(4), 748-761.

Priemer, B., Eilerts, K., Filler, A., Pinkwart, N., Rösken-Winter, B., Tiemann, R., & Zu Belzen, A. (2020). A framework to foster problem-solving in STEM and computing education. Research in Science & Technological Education, 38(1), 105-130.
Saiyad, S., Virk, A., Mahajan, R., & Singh, T. (2020). Online teaching in medical training: Establishing good online teaching practices from cumulative experience. International Journal Of Applied And Basic Medical Research, 10(3), 149.
Sattar, M., Palaniappan, S., Lokman, A., Shah, N., Khalid, U., & Hasan, R. (2020). Motivating medical students using virtual reality based education. International Journal of Emerging Technologies in Learning (iJET), 15(2), 160-174.
Servotte, J., Goosse, M., Campbell, S., Dardenne, N., Pilote, B., Simoneau, I., & Ghuysen, A. (2020). Virtual reality experience: Immersion, sense of presence, and cybersickness . Clinical Simulation in Nursing, 38, 35-43.
Su, K., Chen, S., Lin, P., & Hsieh, C. (2020). Evaluating the user interface and experience of VR in the electronic commerce environment: a hybrid approach. Virtual Reality, 24, 241-254.
Sulai, M., & Sulai, E. (2020). Science, Technology, Engineering and Mathematics (STEM) education: a tool for national development. International Journal of Educational Research, 8(1), 117-126.
Swedberg, R. (2020). Exploratory research. En R. Swedberg, The production of knowledge: Enhancing progress in social science (págs. 17-41.). United Kindom: Univerity Press Cambridge.
Thahir, A., Anwar, C., Saregar, A., Saregar, A., Choiriah, L., Susanti, F., & Pricilia, A. (2020). The Effectiveness of STEM learning: scientific attitudes and students' conceptual understanding. Journal of Physics: Conference Series (Vol. 1467, No. 1, p. 012008). IOP Publishing.
Tsivitanidou, O., Georgiou, Y., & Ioannou, A. (2021). A Learning experience in inquiry-based physics with immersive virtual reality: Student perceptions and an interaction effect between conceptual gains and attitudinal profiles. Journal of Science Education and Technology, 30(6), 841-861.
Zidny, R., Sjöström, J., & Eilks, I. (2020). A multi-perspective reflection on how indigenous knowledge and related ideas can improve science education for sustainability. Science & Education, 29(1), 145-185.