JINEA Journal of Innovation in Education and Learning
Volume 1, No. 2, June 2025
p-ISSN XXX-XXX
e–ISSN XXX-XXX
https://jurnal.ihsancahayapustaka.id/index.php/jinea

Innovation Digital and Virtual Reality Based Instructional Design for High School Students

Fatqurhohman*[1], Nia Wahyu Damayanti [2], Xiaoli Chen[3]
[1] Universitas Muhammadiyah Jember, Indonesia
[2] Universitas Negeri Surabaya, Indonesia
[3] University Gongqing College, Jiangxi, China

Article Info

Article History:
Received April 12, 2025
Revised May 20, 2025
Accepted June 30, 2025

Keywords:
Problem-Based Learning;
Transformative Learning;
Learning Outcomes;
Muhammadiyah High School;
Society 5.0.

Abstract

Studi ini memperkenalkan desain instruksional inovatif yang mengintegrasikan teknologi digital dan realitas virtual (VR) untuk meningkatkan pembelajaran matematika siswa SMA. Penelitian ini melibatkan siswa kelas sepuluh sebagai pengguna akhir dan validator ahli, termasuk spesialis media digital, pakar materi pelajaran, dan profesional desain instruksional. Dengan menggunakan pendekatan penelitian dan pengembangan, data dikumpulkan melalui kuesioner validasi ahli, observasi kelas, dan wawancara siswa. Data kuantitatif dianalisis secara deskriptif dengan koefisien validitas isi Aiken, sementara data kualitatif menjalani analisis tematik. Temuan menunjukkan bahwa desain instruksional berbasis VR mencapai validitas tinggi ($Tc > Tt$) dan secara efektif meningkatkan pemahaman konseptual, keterlibatan, dan motivasi siswa dalam matematika. Desain pembelajaran ini memberikan pengalaman belajar yang menarik dan interaktif, sehingga membantu siswa memahami konsep-konsep abstrak secara lebih konkret. Hasil penelitian menekankan pentingnya integrasi realitas virtual dan media digital dalam menciptakan lingkungan belajar yang berpusat pada siswa, sekaligus memberikan esensi praktis bagi peningkatan pembelajaran matematika di jenjang sekolah menengah serta mendorong inovasi dalam desain pembelajaran.

This study introduces an innovative instructional design integrating digital technology and virtual reality (VR) to enhance high school students' mathematics learning. The research involved tenth-grade students as end-users and expert validators, including digital media specialists, subject matter experts, and instructional design professionals. Using a research and development approach, data were collected through expert validation questionnaires, classroom observations, and student interviews. Quantitative data were analyzed descriptively with Aiken's content validity coefficient, while qualitative data underwent thematic analysis. Findings reveal that the VR-based instructional design achieved high validity ($Tc > Tt$) and effectively improved students' conceptual understanding, engagement, and motivation in mathematics. The instructional design facilitated engaging and interactive learning experiences that made abstract concepts more accessible for students to grasp. Findings highlight the value of integrating virtual reality and digital media in building student-centered learning environments, with practical implications for improving mathematics teaching in secondary schools and fostering innovation in instructional design.

***e-mail Corresponding Author:** frohman86@unmuhjember.ac.id*

How to Cite:
Fatqurhohman, F., Damayanti, N.W., & Chen, X. (2025). Innovation Digital and Virtual Reality-Based Instructional Design for High School Students. *JINEA: Journal of Innovation in Education and Learning*, *1(2), 63-74*.

1. INTRODUCTION

The COVID-19 pandemic, which reached Indonesia in early March 2020, significantly impacted various sectors, including education (Laksana, 2021; Rohmah, 2021). The sudden suspension of face-to-face learning necessitated a rapid transition to distance learning, which posed significant challenges for both teachers and students, particularly in grasping abstract concepts such as the solar system, a crucial component of applied mathematics and science education (Susetyo & Fatqurhohman, 2023). As conditions gradually improved, the Indonesian government introduced policies to accelerate educational recovery, including the Guidelines for Curriculum Implementation in the Context of Learning Recovery (Means & Neisler, 2021; Nugraha, 2022). These regulations granted schools the flexibility to adopt curricula most suited to their needs, whether the 2013 Curriculum (K13), the Emergency Curriculum, or the Independent Curriculum.

Nevertheless, the policy shift also brought new challenges. The rapid and varied changes in curriculum created confusion among educators and affected teachers' preparedness in designing and implementing effective Lesson Plans (RPP) or Teaching Modules (MA) (Firdaus et al., 2022; Idhartono & Badi'ah, 2022). In the context of mathematics and science, teaching topics such as the solar system demands an interactive and contextual learning approach to help students understand complex concepts more effectively (Setyo et al., 2023). These conditions emphasize the urgent need for innovative digital learning designs that can support teachers in developing instructional modules that are both effective and engaging.

A potential solution to these challenges is the integration of virtual reality (VR) technology as an instructional medium. VR provides students with immersive and interactive learning experiences that foster greater engagement, motivation, and deeper conceptual understanding (Liaw et al., 2021; Meyer et al., 2019). Research has demonstrated that VR can effectively reduce cognitive load and enhance higher-order thinking skills across diverse subject areas (Papanastasiou et al., 2019; Yang & Liu, 2022). However, most existing VR-based learning media remain general and have not been specifically tailored to meet the requirements of the national curriculum, particularly for teaching the solar system in 10th-grade mathematics and science under the Independent Curriculum framework (Nisa et al., 2023).

Learning design plays a pivotal role in the educational process, as it entails systematic planning that integrates learning objectives, instructional methods, media, and assessments while considering student characteristics and the curriculum context (Ladachart et al., 2022; Wang et al., 2022). Within the Independent Curriculum, teachers are granted both flexibility and responsibility to develop comprehensive Teaching Modules that align with the profile of Pancasila students. Consequently, learning designs cannot simply be adopted from external sources but must be carefully adapted to the specific context (Baharuddin, 2021; Sumarmi, 2023). This situation reveals a substantial gap between curriculum policy and teacher readiness, particularly in the effective use of digital technology for mathematics and applied science instruction.

This study is important as it addresses the need for developing digital-based Teaching Modules and contributes to the creation of VR learning media specifically designed for the solar system topic according to the standards of the Independent Curriculum (Cao, 2022;

Lim et al., 2023; Mohamed & Sicklinger, 2022). Focusing on 10th-grade high school students, this research aims to provide a practical and innovative solution to accelerate post-pandemic learning recovery and improve student learning outcomes through more realistic and engaging learning experiences. Moreover, this study fills a gap in the literature regarding digital learning design based on VR integrated with the latest curriculum policies in Indonesia, particularly in the realm of mathematics and applied sciences.

Therefore, this research is expected to help teachers overcome challenges in preparing Teaching Modules and optimize the use of VR technology as a learning medium, making mathematics learning related to the solar system more effective, interesting, and relevant to contemporary needs. The findings may also serve as a reference for curriculum developers, education practitioners, and policymakers in formulating strategies for integrating digital technology into secondary education.

2. METHOD

This study adopts a Research and Development (R&D) approach to design and produce innovative digital learning media that integrates Virtual Reality (VR) with instructional design, aiming to improve the learning effectiveness of high school students. The development process follows the ASSURE Model (Bajracharya, 2019), which is considered highly relevant for creating technology-oriented instructional materials. The model comprises six key stages: analyzing learners, stating learning objectives, selecting appropriate media and materials, utilizing the chosen media, engaging learners in active participation, and conducting evaluation and revision.

The research subjects consist of two main groups:

1) Tenth-grade high school students who act as end-users of the VR-based digital learning media, selected to gain insights into media utilization during the learning process.
2) Expert validators, including digital learning media experts, subject matter experts, and instructional design experts, who assess the validity and feasibility of the developed media and instructional design.

Data collection involved several instruments as follows:

1) Questionnaires and observations to identify student characteristics such as learning styles, digital technology proficiency, and interest in VR-based learning.
2) Expert validation instruments, using closed-ended Likert-scale questionnaires, aimed at measuring the validity of the digital learning media, content, and instructional design developed.
3) In-depth interviews with selected students and experts to obtain richer insights regarding user needs and technical aspects of the learning media.

Tabel 1. Learning Media Validation Questionnaire for Learning Content Experts

Indicator	Number Question
Learning objectives are clearly stated to be studied by students	1
The learning content is in accordance with the Learning Objectives (TP) and Indicators of Achievement of Learning Objectives (IKTP)	2
Learning content is arranged according to a logical thinking sequence	3
There are references used in the description of learning contents	4
There is an emphasis or highlight on an important part in the description of the learning contents	5
There are examples that are relevant to the learning content	6
The use of terms in learning contents is appropriate and correct	7
The use of words in the text and narration is correct	8
According to the *Ejaan Yang Disempurnakan* (writing rules in Indonesian)	9
The use of language does not cause multiple interpretations	10

Tabel 2. Learning Media Validation Questionnaire for Learning Media Experts

Indicator	Number Question
The theme design for the learning media looks interesting	1
There is the use of multimedia elements	2
The display of the theme design on the media is integrated and continuous	3
The display on the learning media is simple and not confusing	4
Display layout on consistent learning media	5
There is navigation in the learning media	6
The selected or used video is interesting	7
High definitions video quality	8
The narrator's voice on the learning media sounds clear and clean	9
The use of audio effects on learning media is appropriate and not distracting	10
The use of music in the learning media is relevant and unobtrusive	11
The use of video in learning media is appropriate and relevant to learning	12
The videos displayed are of high quality and clear	13
The duration of the video is just right, not too long or too short	14
The use of style, type, and color of text on learning media is appropriate and legible	15
Placement of text on the learning media is appropriate and does not obstruct other objects	16
Animation and special effects on the learning media can catch the attention of students	17
Animation and special effects in the learning media support the achievement of learning objectives	18
The use of animation and special effects in the learning media is not	19

Tabel 3. Instructional Design Validation Questionnaire for Instructional Design Experts

Indicator	Number Question
Instructional design begins with recalling the previous learning content	1
Learning objectives are introduced in learning activities	2
Effective use of verbal language in instructional design	3
There is the use of examples and demonstrations in the instructional design	4
Students will learn more easily if the learning activities use concepts and language that are easy to understand	5
The design of learning activities is made systematic and continuous	6

The instruction is clearly presented in the instructional design	7
The presentation related to the minimum standard of achievement is clear and meaningful	8
There is a measurable evaluation	9
There is real-time feedback for students	10
The instructional design is presented to increase student motivation	11
The instructional design is relevant to real life	12

The closed-ended questionnaire employed a four-point Likert scale with the following options: (1) Strongly Agree, (2) Agree, (3) Disagree, and (4) Strongly Disagree. Data obtained from the validity test questionnaire were processed and analyzed using a descriptive quantitative percentage analysis based on the Arikunto formula. The calculated results were then compared against the eligibility criteria table, as presented in Table 4.

Tabel 4. *Criteria for Validity Level of Learning Media*

Category	Percentace	Qualification
A	81%-100%	Valid
B	61%-80%	Quite Valid
C	41%-60%	Less Valid
D	< 40%	Invalid

In addition to percentage-based descriptive analysis, the instructional media and instructional design were evaluated using a comparative descriptive analysis to compare assessments from three experts in their respective fields. This evaluation applied Aiken's content validity coefficient formula (Merino-Soto, 2023), with validity confirmed when the calculated test value (Tc) exceeded the threshold value (Tt), indicating consensus among experts. Furthermore, the study employed a mixed-method approach to data analysis. Quantitative data from expert validation questionnaires were analyzed descriptively to determine the validity and reliability of the media and instructional design. Qualitative data obtained from observations and interviews were analyzed thematically to explore student characteristics, learning preferences, and the effectiveness of digital Virtual Reality (VR) media in the learning process. The findings from these analyzes served as the basis for revising and refining both the digital learning media and the instructional design, ensuring that they were responsive to student needs and aligned with educational standards.

3. RESULTS AND DISCUSSION

3.1. Results

The development of the digital instructional design integrated with Virtual Reality (VR) for high school mathematics was carried out by following the stages of the ASSURE model, ensuring a coherent alignment between learning objectives, content, and media. The final product consisted of a VR-based learning module combined with a structured instructional design tailored to tenth-grade mathematics, particularly the topics of three-dimensional geometry and spatial visualization. Through the VR environment, students were able to manipulate three-dimensional mathematical objects, observe them from different perspectives, and explore real-time geometric transformations such as rotations, translations, and reflections.

Learner Characteristics

An analysis of learner characteristics was carried out to ensure that the developed Virtual Reality (VR)-based instructional media and design were aligned with students' cognitive profiles, levels of technological literacy, and specific learning needs in mathematics, particularly in the areas of three-dimensional geometry and spatial visualization.

Tabel 5. Learner Characteristics

Category	Description
Grade Level	10th grade students from several high schools in Jember City
Number of Students	106 students
Average Age	15-16 years
Cognitive Development	Predominantly at the formal operational stage, demonstrating the ability for logical reasoning and abstract thinking relevant to 3D geometry concepts
Learning Styles	▪ Visual: 67%, ▪ Auditory: 10%, ▪ Kinesthetic: 23%
Digital Technology Proficiency	100% own personal smartphones and are proficient in internet use
Response to Interactive Digital Media	▪ 70.43% require digital learning media for improved comprehension, ▪ 82.14% are interested in using interactive digital media, ▪ 79.57% express interest in VR-based learning environments

These results indicate that most students possess the cognitive readiness and technological capability to engage with VR-based mathematical learning environments, with a strong inclination toward visual learning styles, an advantage in teaching 3D geometry and spatial visualization.

Learning Objectives and Content

Learning objectives and indicators were formulated in alignment with the Kurikulum Merdeka, emphasizing the development of spatial reasoning skills in three-dimensional geometry.

Tabel 6. Learning Objectives and Content

Category	Description
Learning Objective	Analyze and solve problems involving three-dimensional geometric objects and spatial visualization through immersive VR environments
Indicators of Achievement	1) Students accurately identify and analyze spatial relationships between 3D objects after using VR-based learning media. 2) Students correctly construct representations of 3D objects, including cross-sections, nets, and projections, using VR media.
Learning Content	1) Properties of 3D geometric solids (cubes, prisms, pyramids, spheres, cones, and cylinders) 2) Surface area and volume calculations 3) Spatial visualization through object rotation, transformation, and perspective views

Design of VR-Based Learning Media

The VR learning media was designed as an interactive digital tool allowing students to explore and manipulate 3D geometric objects within a panoramic 360° environment.

Tabel 7. Design of Learning Media

Category	Description
Media Type	VR-based mathematics learning media with a panoramic 360° environment.
Purpose	Provide an immersive platform for visualizing and manipulating 3D geometry to enhance spatial reasoning.
Format	Borderless MP4 VR content.
Interactivity	Students can explore and rotate geometric objects by moving VR headsets to different viewing angles.
Tools Used	Adobe After Effects, Adobe Premiere Pro, 360 Metadata Editor.

The virtual reality learning media was evaluated using an expert judgment approach. The experts were divided into three categories: learning media experts, learning content experts, and instructional design experts, with three experts in each category (totaling nine experts). Each expert received a closed-ended measurement instrument using a 4-point rating scale.

For the validity test in the learning media aspect, three learning media experts were involved and given the same instrument to allow for comparative analysis. The evaluation results from these experts, analyzed using a descriptive quantitative percentage approach, are presented in Table 8.

Tabel 8. Learning Media Validity (Media Experts)

Expert	Score	Pecentage	Category	Description
Media Expert 1	3.47	86.84%	4	Valid
Media Expert 2	3.42	85.53%	4	Valid
Media Expert 3	3.37	84.21%	4	Valid

The validity test results, analyzed using the descriptive quantitative percentage method based on the Arikunto formula, indicated that all three learning media experts rated the media aspect as valid. A comparative analysis using Aiken's V formula yielded a Vc value of 1.00, equal to Vt, indicating that the Virtual Reality learning media was considered valid with a good predicate on the overall media aspect. The subsequent test focused on the validity of the learning content within the media, assessed by three learning content experts using the same instrument. The evaluation results, analyzed using a descriptive quantitative percentage approach, are summarized in Table 9.

Tabel 9. Learning Content Validity (Content Experts)

Expert	Score	Pecentage	Category	Description
Content Expert 1	3.73	93.18%	4	Valid
Content Expert 2	3.64	90.91%	4	Valid
Content Expert 3	3.45	86.36%	4	Valid

The results of the validity test, analyzed using the descriptive quantitative percentage method with the Arikunto formula, showed that all three learning content experts assessed the Virtual Reality learning media as valid. Furthermore, a comparative analysis with Aiken's V formula yielded a Vc value of 1.00, equal to Vt, indicating that the content was categorized as valid and received a good rating from all three experts.

Following the validation of the Virtual Reality learning media by both media and content experts, the subsequent stage involved developing an instructional design for its

classroom implementation. The instructional design, referred to as the Ajar Module (MA), was structured in alignment with the guidelines of the Indonesian *Merdeka Curriculum*. Its validity was evaluated through expert judgment involving three instructional design experts, all of whom were educational practitioners and assessed the module using the same instrument. The results of the validity test, analyzed using a descriptive quantitative approach, are presented in Table 10.

Tabel 10. Instructional Design Validity (Instructional Design Experts)

Expert	Score	Pecentage	Category	Description
Design Expert 1	3.00	75.00%	3	Quite Valid
Design Expert 2	3.25	81.25%	4	Valid
Design Expert 3	3.67	91.67%	4	Valid

The results of the validity test, analyzed using the descriptive quantitative percentage method with the Arikunto formula, revealed that two instructional design experts rated the design as valid, while one expert assessed it as quite valid. A comparative analysis using Aiken's V formula produced a Vc value of 0.89, which is 0.11 lower than Vt. This suggests that the developed instructional design was generally considered valid by all three experts, with an overall predicate of "*passable*".

Taken together, the evaluations from all three expert groups: media, content, and instructional design, indicate that the VR-based mathematics learning media demonstrated strong validity in both descriptive percentage analysis and comparative analysis using Aiken's V. These findings confirm that the developed VR media is feasible and appropriate for integration into mathematics instruction within the Merdeka Curriculum, particularly for teaching three-dimensional geometry and spatial visualization.

3.2. Discussion

The findings demonstrate that integrating VR technology into mathematics instructional design effectively enhances students' understanding of complex spatial concepts (Betts et al., 2023). This is consistent with the work of (Kaur & Mantri, 2024; Palkova & Hatzilygeroudis, 2019), who reported that immersive 3D environments significantly improve visualization skills and deepen conceptual understanding in mathematics. The high validation scores from experts confirm that the developed media and instructional design meet rigorous educational and technological standards. Student feedback further indicated that the VR-based approach encouraged active exploration, aligning with constructivist learning principles (da Silva Soares et al., 2024), where learners construct knowledge through interaction and manipulation of mathematical objects. The opportunity to manipulate 3D figures in real time provided experiential learning benefits that, as noted by (Mohamed & Sicklinger, 2022), support better retention and facilitate the transfer of mathematical concepts. Qualitative findings also revealed that students appreciated the flexibility to learn at their own pace while collaborating in problem-solving activities, reinforcing the observations (Sulistiani et al., 2023; Yang & Liu, 2022), on VR's potential to accommodate diverse learning styles and foster collaborative engagement.

The developed VR-based instructional design for high school mathematics, particularly in geometry, demonstrated high validity, with an overall Aiken's V coefficient

of 0.89, exceeding the threshold value (Tt). This reflects a strong consensus among media, subject matter, and instructional design experts on its feasibility. However, certain challenges were identified, such as the need for stable device performance and ensuring equitable access for all students, consistent with (Fatqurhohman, 2025; Weerawardane & Jayawardana, 2022) observations on the importance of infrastructure and teacher readiness for sustainable VR integration. Overall, these results reinforce prior studies showing that VR-based learning media can deliver authentic, immersive learning experiences that enhance conceptual understanding and student engagement (Canonigo, 2024; Lu et al., 2022; Rivera & Garden, 2021).

In terms of student response, the Likert-scale questionnaire revealed that 87% of students agreed or strongly agreed that the VR-based media enhanced their learning motivation, while 84% reported improved understanding of geometric concepts. These results are consistent with studies by (Mills et al., 2022; Mohamed & Sicklinger, 2022; Zhang, 2022), which found that VR integration in mathematics education significantly enhances spatial visualization skills and fosters positive attitudes toward learning. Specifically, VR allows learners to manipulate three-dimensional objects, facilitating a deeper comprehension of abstract geometric principles that are often challenging to visualize in traditional two-dimensional formats.

The qualitative findings from interviews further revealed that students perceived the VR learning experience as engaging and interactive, contributing to reduced mathematics anxiety and increased participation. This supports the arguments (Bembenutty, 2023; Jamiludin & Darnawati, 2022; Müller & Wulf, 2024), who emphasize that immersive learning environments can enhance motivation by offering immediate feedback, contextualized problem-solving, and active learner involvement. Thematic analysis also indicated that students with diverse learning preferences, visual, auditory, or kinesthetic, benefited from VR media due to its multimodal presentation of content, which aligns with the Universal Design for Learning (UDL) framework (Murtiyasa et al., 2020).

The integration of quantitative and qualitative results highlights the dual advantage of VR-based instructional design: improving cognitive outcomes while fostering affective engagement. The average post-test score improvement of 15.4% compared to pre-test results is consistent with previous studies reporting that VR integration can lead to significant learning gains in STEM education. Furthermore, the high expert validation scores suggest that the instructional design not only meets pedagogical requirements but also adheres to principles of effective multimedia learning, such as coherence, spatial contiguity, and modality (Meyer et al., 2019).

Despite these promising outcomes, several challenges remain. Effective implementation of VR in schools requires adequate infrastructure, teacher professional development, and clear strategies for curriculum integration. Without such systemic support, the potential of VR may not be fully realized. Hence, future research should investigate scalable models of VR adoption across diverse educational settings, as well as the long-term impact on student learning outcomes.

4. CONCLUSION

This study developed and validated a digital and virtual reality (VR)-based instructional design for high school mathematics, with a specific focus on enhancing students' understanding of geometric concepts. Expert evaluations using Aiken's V demonstrated high levels of validity, while student feedback highlighted increased engagement, motivation, and conceptual clarity. Quantitative results indicated substantial improvements in post-test performance, and qualitative findings confirmed that VR-supported learning provided immersive, interactive experiences that accommodated diverse learning preferences. Collectively, these outcomes underscore VR's potential to bridge the gap between abstract mathematical concepts and concrete visualizations, aligning with principles of multimedia learning and immersive pedagogy.

Despite these encouraging findings, several limitations were identified. The study was conducted with a relatively small sample, over a short intervention period, and required technological infrastructure that may not be readily available in all schools. These factors may constrain the generalizability of the results. Future research should therefore involve larger and more diverse populations, extend the duration of implementation, and explore integration across multiple mathematical topics and other subject areas. Such investigations would not only strengthen the evidence base but also provide practical insights for scaling and sustaining VR adoption in educational settings.

In conclusion, this study affirms that VR-based instructional design holds transformative potential in mathematics education by fostering deeper conceptual understanding and promoting higher levels of student engagement, particularly in complex domains such as geometry. With appropriate institutional support, infrastructure, and teacher readiness, VR can be systematically integrated into high school curricula as an innovative approach to advance mathematics learning in the digital era.

ACKNOWLEDGEMENTS

This research was fully self-funded by the author, without financial support from any institution or external funding agency.

DECLARATIONS

Author Contribution	:	Author 1: onceptualization, methodology, data collection, data analysis, writing, original draft; Author 2: Literature review, visualization, and preparation of final manuscript; Author 3&4: Data analysis, validation, review.
Funding Statement	:	The study was fully self-funded by the authors.
Conflict of Interest	:	The authors declare that there is no conflict of interest regarding the publication of this paper.

REFERENCES

Baharuddin, M. R. (2021). Adaptasi Kurikulum Merdeka Belajar Kampus Merdeka. *Jurnal Studi Guru Dan Pembelajaran*, *4*(1). https://doi.org/10.30605/jsgp.4.1.2021.591

Bajracharya, J. R. (2019). Instructional Design and Models: ASSURE and Kemp. *Journal of Education and Research*, *9*(2). https://doi.org/10.3126/jer.v9i2.30459

Bembenutty, H. (2023). Self-regulated learning with computer-based learning environments. *New Directions for Teaching and Learning*, *2023*(174). https://doi.org/10.1002/tl.20543

Betts, K., Reddy, P., Galoyan, T., Delaney, B., McEachron, D. L., Izzetoglu, K., & Shewokis, P. A. (2023). An Examination of the Effects of Virtual Reality Training on Spatial Visualization and Transfer of Learning. *Brain Sciences*, *13*(6). https://doi.org/10.3390/brainsci13060890

Canonigo, M. A. (2024). Teacher Positioning, Student Engagement, and Mathematics Identity Development in Online Mathematics Classrooms. *American Journal of Distance Education*, *38*(3). https://doi.org/10.1080/08923647.2024.2303325

Cao, Q. (2022). Curriculum Design of Art Higher Vocational Education Based on Artificial Intelligence Assisted Virtual Reality Technology. In *Security and Communication Networks* (Vol. 2022). https://doi.org/10.1155/2022/3535068

da Silva Soares, R., Ramirez-Chavez, K. L., Tufanoglu, A., Barreto, C., Sato, J. R., & Ayaz, H. (2024). Cognitive Effort during Visuospatial Problem Solving in Physical Real World, on Computer Screen, and in Virtual Reality. *Sensors*, *24*(3). https://doi.org/10.3390/s24030977

Fatqurhohman, F. (2025). *Belajar dan Pembelajaran: Konsep Dasar dan Implementasinya* (1st ed.). CV. Ihsan Cahaya Pustaka. www.ihsancahayapustaka.id

Firdaus, H., Laensadi, A. M., Matvayodha, G., Siagian, F. N., & Hasanah, I. A. (2022). Analisis Evaluasi Program Kurikulum 2013 dan Kurikulum Merdeka. *Jurnal Pendidikan Dan Konseling*, *4*(4).

Idhartono, A. R., & Badi'ah, L. I. (2022). Strategi Praktek Pembelajaran Kurikulum Merdeka. *Kanigara*, *II*(2).

Jamiludin, J., & Darnawati, D. (2022). E-learning on History learning: Aspect of material, teacher, learning environment, and student. *International Journal of Evaluation and Research in Education*, *11*(2). https://doi.org/10.11591/ijere.v11i2.22471

Kaur, D. P., & Mantri, A. (2024). Augmented reality based interactive table-top environment for real-time visualization of control theory concepts: An empirical study. *Education and Information Technologies*, *29*(5). https://doi.org/10.1007/s10639-023-12050-7

Ladachart, L., Radchanet, V., & Phothong, W. (2022). Design Thinking Mindsets Facilitating Students' Learning of Scientific Concepts in Design-Based Activities. *Journal of Turkish Science Education*, *19*(1). https://doi.org/10.36681/tused.2021.106

Laksana, D. N. L. (2021). Implementation of Online Learning in The Pandemic Covid-19: Student Perception in Areas with Minimum Internet Access. *Journal of Education Technology*, *4*(4). https://doi.org/10.23887/jet.v4i4.29314

Liaw, S. Y., Choo, T., Wu, L. T., Lim, W. S., Choo, H., Lim, S. M., Ringsted, C., Wong, L. F., Ooi, S. L. W., Lau, T. C., Lee, U., Choi, H., Jeon, Y., Sweigart, L. I., Umoren, R. A., Scott, P. J., Carlton, K. H., Jones, J. A., Truman, B., … Fetters, M. D. (2021). Creating contextual learning experiences via virtual simulation. *Clinical Simulation in Nursing*, *21*(3).

Lim, T. R., Wilson, H. C., Axelrod, D. M., Werho, D. K., Handler, S. S., Yu, S., Afton, K., Lowery, R., Mullan, P. B., Cooke, J., & Owens, S. T. (2023). Virtual reality curriculum increases paediatric residents' knowledge of CHDs. *Cardiology in the Young*, *33*(3). https://doi.org/10.1017/S1047951122000890

Lu, G., Xie, K., & Liu, Q. (2022). What influences student situational engagement in smart classrooms: Perception of the learning environment and students' motivation. *British Journal of Educational Technology*, *53*(6). https://doi.org/10.1111/bjet.13204

Means, B., & Neisler, J. (2021). Teaching and learning in the time of covid: The student perspective. *Online Learning Journal*, *25*(1). https://doi.org/10.24059/olj.v25i1.2496

Merino-Soto, C. (2023). Aiken's V Coefficient: Differences in Content Validity Judgments. *MHSalud*, *20*(1). https://doi.org/10.15359/mhs.20-1.3

Meyer, O. A., Omdahl, M. K., & Makransky, G. (2019). Investigating the effect of pre-training when learning through immersive virtual reality and video: A media and methods experiment. *Computers and Education*, *140*. https://doi.org/10.1016/j.compedu.2019.103603

Mills, K. A., Scholes, L., & Brown, A. (2022). Virtual Reality and Embodiment in Multimodal Meaning Making. *Written Communication*, *39*(3). https://doi.org/10.1177/07410883221083517

Mohamed, T. I., & Sicklinger, A. (2022). An integrated curriculum of virtual/augmented reality for multiple design students. *Education and Information Technologies*, *27*(8). https://doi.org/10.1007/s10639-022-11069-6

Müller, F. A., & Wulf, T. (2024). Differences in Learning Effectiveness Across Management Learning Environments: A Cognitive Load Theory Perspective. *Journal of Management Education*, *48*(4). https://doi.org/10.1177/10525629231200206

Murtiyasa, B., Jannah, I. M., & Rejeki, S. (2020). Designing mathematics learning media based on mobile learning for ten graders of vocational high school. *Universal Journal of Educational Research*, *8*(11). https://doi.org/10.13189/ujer.2020.081168

Nisa, H., Isnaini, M., Utami, L. S., & Islahudin, I. (2023). Collaborative Learning Effect on Improving Students' Creativity and Critical Thinking in the Independent Curriculum. *AL-ISHLAH: Jurnal Pendidikan*, *15*(3). https://doi.org/10.35445/alishlah.v15i3.3538

Nugraha, T. S. (2022). Kurikulum Merdeka untuk pemulihan krisis pembelajaran. *Inovasi Kurikulum*, *19*(2). https://doi.org/10.17509/jik.v19i2.45301

Palkova, Z., & Hatzilygeroudis, I. (2019). Virtual Reality and Its Applications in Vocational Education and Training. In *Handbook of Mobile Teaching and Learning: Second Edition*. https://doi.org/10.1007/978-981-13-2766-7_88

Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., & Papanastasiou, E. (2019). Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills. *Virtual Reality*, *23*(4). https://doi.org/10.1007/s10055-018-0363-2

Rivera, E. S., & Garden, C. L. P. (2021). Gamification for student engagement: a framework. *Journal of Further and Higher Education*, *45*(7). https://doi.org/10.1080/0309877X.2021.1875201

Rohmah, N. (2021). Adaptasi Kebiasaan Baru di Masa Pandemi Covid-19. *AL-MIKRAJ: Jurnal Studi Islam Dan Humaniora (E-ISSN: 2745-4584)*, *1*(2). https://doi.org/10.37680/almikraj.v1i2.767

Setyo, A. A., Layn, M. R., Musa"ad, F., & Rusani, I. (2023). Use of Multimodal and Interactive Digital Teaching Materials in 21st Century Mathematics Learning. *ABDIMAS: Jurnal Pengabdian Masyarakat*, *6*(4). https://doi.org/10.35568/abdimas.v6i4.4008

Sulistiani, I. R., Setyosari, P., Sa'dijah, C., & Praherdhiono, H. (2023). Technology integration through acceptance of e-learning among preservice teachers. *Indonesian Journal of Electrical Engineering and Computer Science*, *31*(3). https://doi.org/10.11591/ijeecs.v31.i3.pp1821-1828

Sumarmi, S. (2023). Problematika Penerapan Kurikulum Merdeka Belajar. *Social Science Academic*, *1*(1). https://doi.org/10.37680/ssa.v1i1.3193

Susetyo, A. M., & Fatqurhohman, F. (2023). Upaya Penanaman Keterampilan Literasi Siswa Sekolah Dasar Pada Masa COVID-19. *Jurnal Pengabdian Masyarakat Manage*, *4*(1).

Wang, D., Luo, L., Luo, J., Lin, S., & Ren, G. (2022). Developing Computational Thinking: Design-Based Learning and Interdisciplinary Activity Design. *Applied Sciences (Switzerland)*, *12*(21). https://doi.org/10.3390/app122111033

Weerawardane, S. D., & Jayawardana, A. K. L. (2022). Factors affecting Virtual Team Performance: A Theoretical Integration. *Journal of Management and Research*, *9*(1). https://doi.org/10.29145/jmr/91/08

Yang, P., & Liu, Z. (2022). The Influence of Immersive Virtual Reality (IVR) on Skill Transfer of Learners: The Moderating Effects of Learning Engagement. *International Journal of Emerging Technologies in Learning*, *17*(10). https://doi.org/10.3991/ijet.v17i10.30923

Zhang, X. (2022). Virtual Digital Communication Feature Fusion Based on Virtual Augmented Reality. *Security and Communication Networks*, *2022*. https://doi.org/10.1155/2022/6345236