ISSN 2807-9329 (Print) ISSN 2807-9167 (Online)

Journal of Mathematics, Science and Computer Education (JMSCEdu)

>>> https://ppjp.ulm.ac.id/journals/index.php/jmsc-edu <<<

The Development of Virtual Reality-Based Physics Learning Media on Kepler's Law Topic

Maruf*, Ana Dhiqfaini Sultan, and Suci Haerunnisa
Physics Education Department, Faculty of Teacher and Training Education
Universitas Muhammadiyah Makassar, Makassar, Indonesia
*maruf@unismuh.ac.id

Received: 19 March 2024 **Accepted: 17 April 2024** **Published: 21 April 2024**

DOI: https://doi.org/10.20527/jmscedu.v4i1.12121

Abstract

This study aimed to determine the validity and practicality of virtual reality-based physics learning media on the topic of Kepler's laws. The number of participants in this research was 32 students and two teachers. The research method used was the R&D research method and the ADDIE approach. Data analysis was conducted using the Gregory test and the results of the data analysis. The virtual reality-based physics learning media on the topic of Kepler's laws has high content validity, with an average score of 0.97, and the results show that both the teachers and students had a high level of cognitive, affective, and conative responses to the VR-based learning medium. The average cognitive response was 80%, the average affective response was 85%, and the average conative response was 80%. Overall, the high level of response from the teachers and students suggests that the VR-based learning medium is practical for teaching Kepler's laws to physics students. These results demonstrate that the virtual reality-based learning medium is an effective tool for teaching and learning about Kepler's laws interactively and visually.

Keywords: Kepler's law; physics learning media; virtual reality

How to cite: Maruf, M., Sultan, A. D., & Haerunnisa, S. (2024). The development of virtual reality-based physics learning media on kepler's law topic. *Journal of Mathematics, Science, and Computer Education*, 4(1), 49-57.

INTRODUCTION

Education transfers knowledge, skills, and values from one generation to another. In recent years, the use of technology in education has increased significantly. Virtual reality is one of the technologies that has gained popularity in the field of education (Georgiou et al., 2021). VR is a computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors (Budi et al., 2019); Judkovsky et al., 2022; Kavanagh et al., 2017).

The use of VR in education has the potential to enhance the learning experience by providing a more immersive and interactive environment for students. Studies have shown that VR can improve students' motivation, engagement, and learning outcomes (Georgiou et al., 2021; Suliyanah et al., 2021). In physics education, VR can simulate complex physical phenomena, such as the motion of celestial bodies, which can be challenging to observe and understand in the real world (Georgiou et al., 2021). One of the topics in physics that can be taught using VR is Kepler's laws of planetary motion because this topic has many misconceptions for high school students. Besides that, Kepler's law, especially regarding the circulation of planetary motion, has not provided appropriate visual illustrations in media (Ismail et al., 2022).

Kepler's laws describe the motion of planets around the sun and are among the most important laws in astronomy. However, understanding these laws can be challenging for students, especially those with difficulty visualizing and comprehending abstract concepts (Judkovsky et al., 2022). Using VR to teach Kepler's laws can help students better understand and retain the concepts, as they can interact with and explore the laws more physically (Matos et al., 2023). Previous research has also shown that the use of VR in teaching astronomy can improve students' spatial visualization skills and their understanding of celestial mechanics (Munawaroh et al., 2021).

Virtual reality (VR) technology has gained increasing popularity in education in recent years. VR is a computer-generated simulation of a three-dimensional image or environment that a person can interact with in a seemingly real or physical way using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors (Ismail et al., 2022). The use of VR in education has the potential to enhance the learning experience by providing a more immersive and interactive environment for students.

Studies have shown that using VR in education can improve students' motivation, engagement, and learning outcomes (Judkovsky et al., 2022; Kavanagh et al., 2017). VR can also be used to simulate complex physical phenomena, such as the motion of celestial bodies, which can be difficult to observe and understand in the real world (Paszkiewicz et al., 2021). In physics education, VR has been used to teach various topics, such as electricity, waves, and thermodynamics (Rojas-Sánchez et al., 2023).

One of the topics in physics that has been studied in relation to VR is Kepler's laws of planetary motion. Kepler's laws describe the motion of planets around the sun and are among the most important laws in astronomy; tenth-grade high school students study the topic of Kepler's laws for the new curriculum in Indonesia. However, understanding these laws can be challenging for students, especially those with difficulty visualizing and comprehending abstract concepts. Using VR to teach Kepler's laws can help students better understand and retain the concepts, as they can interact with and explore the laws more physically. In summary, the literature suggests that using VR in physics education, including in teaching Kepler's laws, can potentially improve students' motivation, engagement, and learning outcomes. However, more research is needed to determine the practicality and validity of VR-based physics learning media on Kepler's laws (Marougkas et al., 2024).

Considering the usefulness of virtual reality as learning media to help the teacher deliver learning content, researchers developed virtual reality-based learning media based on Kepler's Law. The research was conducted to develop a learning medium that is suitable for research based on the validity of expert and students' responses.

METHOD

The research method used in this study is research and development (R&D), as proposed by Gall (Gall & Borg et al., 2003; Irfandi et al., 2023). R&D is a systematic approach to the design, development, and evaluation of new or revised educational products or programs. It involves a series of steps, including needs assessment, design, development, implementation, and evaluation.

In this study, the R&D method was used with the ADDIE approach, a widely used instructional design model. The ADDIE approach consists of five phases: 1). The initial analysis stage starts from the analysis of the characteristics of students, the analysis of the material being taught, and the competencies to be delivered; 2) The design stage is the stage of carrying out the initial design of the form of virtual reality being developed; 3) The development stage is the stage of completing the initial product, instrument and product validation; 4) implementation stage, namely conducting trials at schools that are research locations; 5) evaluation stage, namely evaluating trial results to ensure that the research objectives are achieved well. In the analysis phase, the needs of the users were analyzed. It was observed that using learning media at SMAN 8 Gowa for Kepler's laws was limited to textbooks and PowerPoint presentations. In the design phase, two software programs were used: Unity and Visual Studio Code. Unity was used to design animations, while Visual Studio Code was used as a coding and implementation platform. In the development phase, two media experts developed and tested the VR-based learning medium to determine its validity. The VR-based learning medium was implemented in the implementation phase with a sample of 32 physics students and two physics teachers. The learning was carried out over three meetings according to the number of lesson hours in the school curriculum for tenth-grade physics subjects. The goal of this phase was to determine the practicality of the media based on the responses of the teachers and students through a survey. In the evaluation phase, the VR-based learning medium was revised based on the feedback obtained during the implementation phase. The goal of this phase was to determine the effectiveness of the media in improving student learning outcomes. Overall, the R&D approach with the ADDIE approach was used to develop and assess the practicality and validity of the VR-based learning medium on the topic of Kepler's laws.

In the data analysis, the Gregory test was used to determine the validity of the VR-based learning medium. The Gregory test is a commonly used method for evaluating the validity of instructional materials (Sultan, 2021). It involves reviewing and assessing the materials by experts in the field to determine their accuracy, completeness, and effectiveness in achieving the intended learning objectives. In this study, two media experts reviewed and assessed the VR-based learning medium. These two expert validators have a background in physics learning media and can assess the media and its physics content. The experts were asked to evaluate the materials based on a set of criteria, including the clarity of the content, the quality of the animations, the interface's usability, and the materials' overall effectiveness in achieving the learning objectives. The results of the Gregory test were used to make revisions to the VR-based learning medium as needed. In addition to the Gregory test, a survey was administered to the students and teachers who used the VR-based learning medium during the implementation phase. The survey included questions about the students' and teachers' perceptions of the practicality and effectiveness of the materials. The survey results were used to further refine the VR-based learning medium and improve its practicality. Overall, this study's data analysis phase included the Gregory test and a survey to assess the validity and practicality of the VR-based learning medium on the topic of Kepler's laws.

The mechanism for calculating content validity testing, according to Gregory, is as follows:

a. Experts are trusted to assess the instrument and evaluate the instrument item by item.
b. Scale classification, appropriate and inappropriate. The results of the expert assessments are cross-tabulated, for example, for two assessors as validators.

Table 1 Inter-rater agreement model for media validation

Validator I	**Validator II**	**1-2**	**3-4**
1-2	1-2	A	B
3-4	3-4	C	D

Validation Criteria:

0.80-1.00 : very high content validation
0.60-0.79 : high content validation
0.40-0.59 : moderate content validation
0.20-0.39 : low content validation
0.00-0.19 : very low content validation

Two media experts used validity research to determine media validation from 18 statements covering three aspects, while the practicality assessment consisted of 21 student response questionnaire statements and 15 teacher response questionnaire statements. The practicality analysis of the developed product can be seen from the practicality test sheets filled out by teachers and students. The answers from each instrument (teacher and student response sheets) that use a Likert scale have detailed scores in Table 2.

Table 2 Response test questionnaire score

Alternative	Positive Score	Negative Score
Strongly Agree (SA)	5	1
Agree (A)	4	2
Doubt (D)	3	3
Disagree (DS)	4	2
Strongly Disagree (SD)	1	5

The feasibility assessment of the test questionnaire uses percentages. Questionnaire score interpretation criteria can be seen in the following Table 3.

Table 3 Response test criteria

Intervals	Criteria
81% < X ≤ 100%	Very positive
61% < X ≤ 80%	Positive
41% < X ≤ 60%	Positive Enough
21% < X ≤ 40%	Less Positive
0% < X ≤ 20%	Not Positive

RESULT AND DISCUSSION

The research and development carried out has resulted in a product in virtual reality-based learning media developed with the ADDIE development model. Before developing the media, a needs assessment was conducted to determine if students needed a learning medium for Kepler law topics. Based on interviews with subject teachers, it was found that current methods of learning Kepler's laws are manual and rely on written explanations and illustrations in textbooks. This can make it difficult for students to understand and apply these laws daily. According to physics subject teachers, the percentage of student learning outcomes for physics subjects, especially on Kepler's laws, is still low compared to other topics, namely only 43.00 percent. Therefore, a media that provides visualizations of Kepler's laws can help improve students' understanding and facilitate the teacher's explanations. Interactive media, such as virtual reality technology, offers a new approach to teaching physics. Unity 3D and VsCode were used in the design process to create the media. Storyboards and user interface design were also important in planning and building the media. The user interface should be visually appealing and easy to use to enhance the user's experience.

In the third stage of development, 3D objects, including planets and the sun, were created. The texturing process, which involves adding texture and color to the object, is then carried out. Next, a lighting process is applied to give a realistic appearance to the object through the use of shadows. This process helps create a more immersive and engaging experience for users. This 3D design process is carried out using a 3D application with a model and appearance as shown in Figure 1.

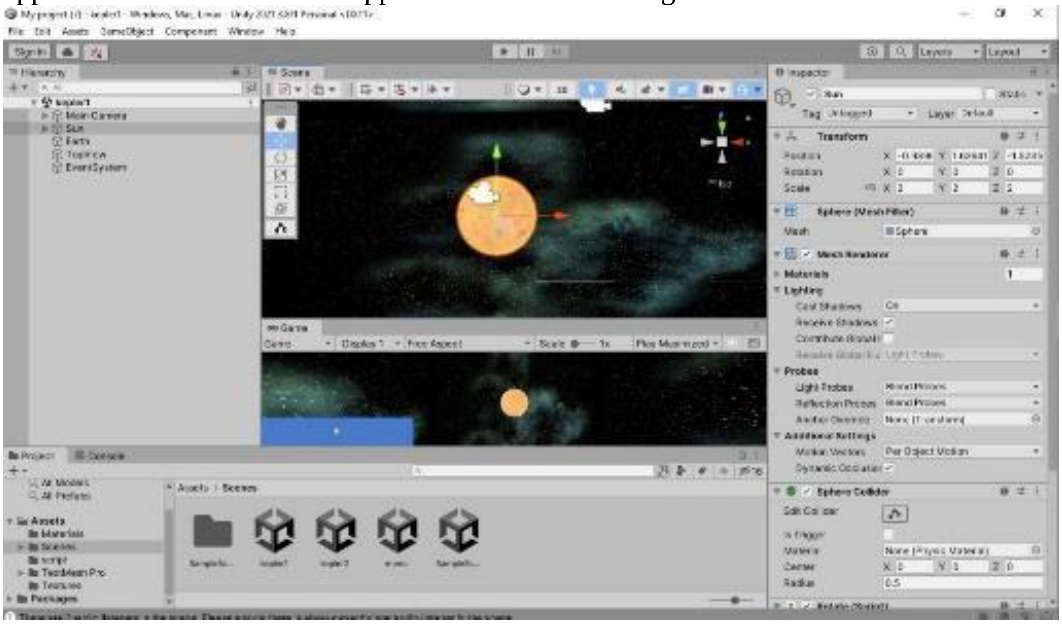


Figure 1 Development in unity

In the next step, these objects are connected and arranged in such a way that they represent the desired shape. Coding using the C# programming language was done using Vscode to create useful scripts that control planetary rotation and revolution, planetary orbits, and other media elements. This script ensures that media displays and animations accurately reflect Kepler's laws. The form and design of the script and program code used are in accordance with the display in Figure 2.

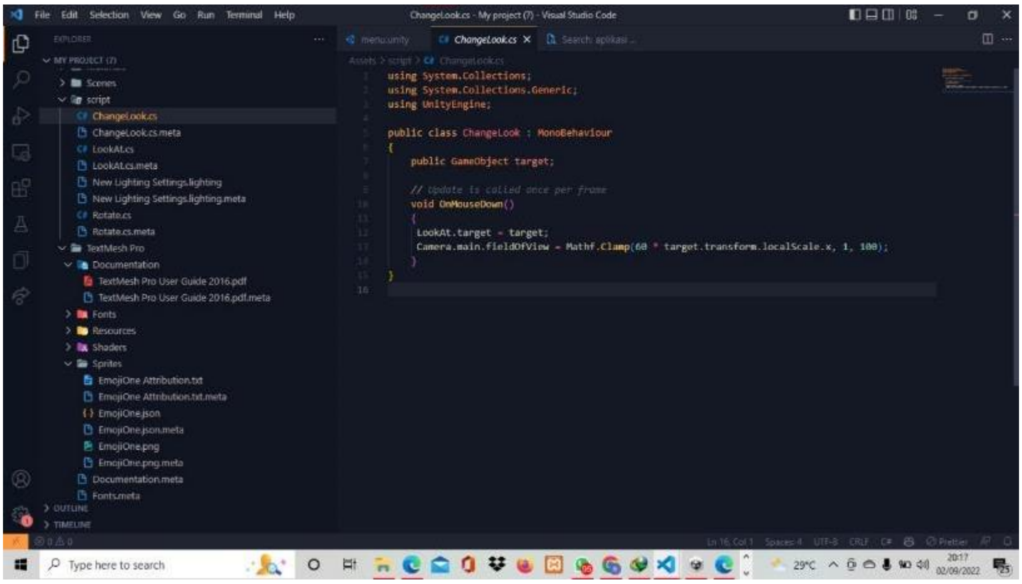
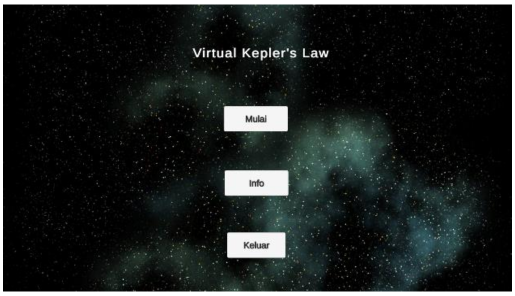


Figure 2 Coding in VsCode

After all media elements are created and coded, the media is exported in EXE format, so it can be used on various computers and laptops. The resulting media can be used to study and teach Kepler's laws through interactive visual experiences. As for the shape of the initial image display when it is installed, the shape is the same as in Figure 3.

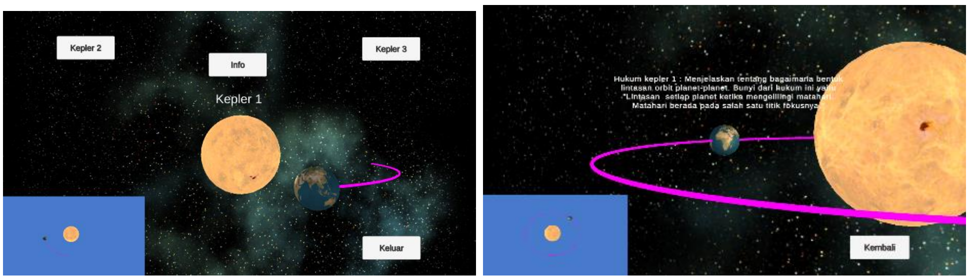
Figure 3 Splash screen

The splash screen is the first screen displayed when the user launches the application. It typically contains the software's logo used to create the media, in this case, the Unity logo. The splash screen serves as a loading screen and includes other information or graphics. It is usually displayed briefly before the main user interface of the medium is shown.



(a)

(b)



(c)

Figure 4 (a) Main Menu, (b) Menu Info, and (c) Kepler’s 1st Law

The start menu of the medium offers the user the option to view animations of Kepler's laws 1-3. There is also an info menu that displays explanations of each of the laws and allows the user to zoom in on the sun or zoom out to view the planets. A back button is provided to return to the previous view. The media also includes an exit menu allowing users to return to the main menu. Overall, the media provides an interactive and visual learning experience for users, helping them understand and apply Kepler's laws.

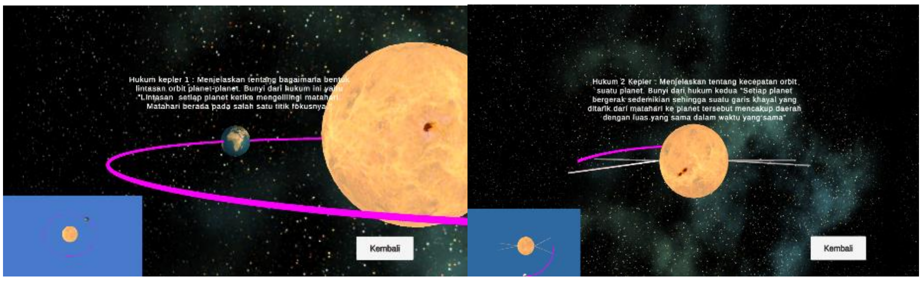


Figure 5 Kepler’s 2nd and 3rd Law

The results of the evaluation of the VR-based learning medium by two media experts are shown in Table 4. The learning medium was evaluated on three aspects: presentation feasibility, feasibility, and language. The ratings were based on a scale of 0 to 1, with 1 being the highest rating.

Table 4 Results of the Gregory Test of The VR-based learning medium

No.	Aspect	Score
1	Content Feasibility	0.97
2	Presentation Feasibility	1.00
3	Language Feasibility	1.00

The results show that the VR-based learning medium was rated as excellent on all three aspects. The content was considered highly feasible, with a rating of 0.97. The presentation was also rated as excellent, with a rating of 1.00. Finally, the language was considered to be of the highest quality, with a rating of 1.00. Overall, the results of the Gregory test suggest that the VR-based learning medium is highly valid and suitable for teaching Kepler's laws to physics students.

The results of the questionnaire responses, which evaluated the practicality of the VR-based physics learning media for teaching Kepler's laws, are shown in Table 5. The survey included questions about the cognitive, affective, and conative responses of the teachers and students to the media. The questionnaire was given after attending physics learning for three meetings, namely at the fourth meeting.

Table 5 The Results of the questionnaire responses

Response	Teachers	Students
Cognitive	80%	80%
Affective	85%	86%
Conative	80%	80%

The resultsin Table 5 show that the teachers and students had a high level of cognitive, affective, and conative responses to the VR-based learning medium. The average cognitive response was 80%, the average affective response was 85%, and the average conative response was 80%. Overall, the high level of response from the teachers and students suggests that the VR-based learning medium is practical for teaching Kepler's laws to physics students.

The results of the study show that the VR-based learning medium developed for teaching Kepler's laws to physics students is highly valid and practical. The results of the Gregory test indicated that the media received excellent ratings on all three aspects evaluated: content feasibility, presentation feasibility, and language feasibility. The average rating for content feasibility was 0.97, which suggests that the media has a high level of content validity. The media also received excellent ratings for presentation feasibility and language feasibility, indicating that it is well-designed and easy to use. In addition, the survey results showed that teachers and students had a high level of cognitive, affective, and conative responses to the media. The average cognitive response was 80%, the average affective response was 85%, and the average conative response was 80%.

These results suggest that the medium is effective in promoting cognitive learning, as well as engaging and motivating students. The findings of this study are consistent with previous research on the use of VR in education (Ma'Ruf et al., 2020; Maruf & Dhiqfaini, 2021; Dhiqfaini Sultan et al., 2023). These studies have shown that VR can be an effective and engaging tool for teaching various subjects, including physics. The use of VR allows students to experience concepts and phenomena in a more immersive and interactive way, which can enhance their understanding and retention of the material (Maruf et al., 2021; Mahrani et al., 2023; Ma'ruf et al., 2020). Overall, the results of this study suggest that the VR-based learning medium developed for teaching Kepler's laws to physics students is a valuable resource that can be used effectively in the classroom. The media's high level of validity and practicality make it a useful tool for enhancing student learning and engagement in the subject.

CONCLUSION

Based on the research, development, and evaluation of the virtual reality-based learning media based on Kepler's Law, it can be concluded that the medium is highly suitable for use by high school students. This conclusion is supported by the media's high content validity, with an average score of 0.97, and by the positive response from physics teachers and students, who rated the media at 82%. These results demonstrate that the virtual reality-based learning medium is an effective tool for teaching and learning about Kepler's laws interactively and visually.

REFERENCES

Budi, A. S., Muliyati, D., Ambarwulan, D., & Bakri, F. (2019). The development of ICT-based learning curriculum for pre-service physics teacher. *Journal of Physics: Conference Series*, *1318*(1). https://doi.org/10.1088/1742-6596/1318/1/012137

Dhiqfaini Sultan, A., Ma, ruf, Kurniawan, R., Nurfadillah, N., Ariani, A., & Hasbi Assidiq, M. (2023). Design and Analysis of the Basic Physics Practicum Model Based on the Higher Order Thinking Laboratory as a Model for 21st Century Learning Practicum. *European Online Journal of Natural and Social Sciences*, *12*(2), 233–240.

Gall & Borg, Meredith D. Gall, Walter R. Borg, & Joyce P. Gall. (2003). *Educational Research_ An Introduction (7th Edition)*.

Georgiou, Y., Tsivitanidou, O., & Ioannou, A. (2021). Learning experience design with immersive virtual reality in physics education. In *Educational Technology Research and Development* (Vol. 69, Issue 6). Springer US. https://doi.org/10.1007/s11423-021-10055-y

Irfandi, I., Sudarma, T. F., Festiyed, F., Yohandri, Y., Diliarosta, S., Surahman, D., & Siregar, A. M. (2023). E-learning and physics teaching materials based on malay ethnoscience on the east coast. *Jurnal Pendidikan IPA Indonesia*, *12*(3), 366–376. https://doi.org/10.15294/jpii.v12i3.45442

Ismail, F. N. B., Mohtar, L. E. B., & Al-Zuhairi, O. A. F. (2022). Development and usability of "gravigame" in kepler's law among physics trainee teacher. *Journal of Physics: Conference Series*, *2309*(1). https://doi.org/10.1088/1742-6596/2309/1/012045

Judkovsky, Y., Ofir, A., & Aharonson, O. (2022). Physical Properties and Impact

Parameter Variations of Kepler Planets from Analytic Light-curve Modeling. *The Astronomical Journal*, *163*(2), 91. https://doi.org/10.3847/1538-3881/ac3d96

Kavanagh, S., Luxton-Reilly, A., & Wuensche, B. (2017). A systematic review of virtual reality in education - the open university. *Themes in Science & Technology Education*, *10*(2), 85–119.

Ma'Ruf, M., Handayani, Y., Marisda, D. H., & Riskawati, R. (2020). The needs analysis of basic physics learning devices based on hybrid learning. *Journal of Physics: Conference Series*, *1422*(1). https://doi.org/10.1088/1742-6596/1422/1/012029

Ma'ruf, M., Setiawan, A., Suhandi, A., & Siahaan, P. (2020). Identification of the ability to solve the problem of contextual physics possessed by prospective physics teachers related to basic physics content. *Journal of Physics: Conference Series*, *1521*(2). https://doi.org/10.1088/1742-6596/1521/2/022011

Mahrani, M., Maruf, M., Bancong, H., & ... (2023). Development of TPACK-oriented teaching materials assisted by google sites in science learning for elementary schools. *European Online Journal of Natural and Social Sciences*, *12*(4), 360–374. https://european-science.com/eojnss/article/view/6827

Marougkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2024). How personalized and effective is immersive virtual reality in education? A systematic literature review for the last decade. In *Multimedia Tools and Applications* (Vol. 83, Issue 6). Springer US. https://doi.org/10.1007/s11042-023-15986-7

Maruf, M., & Dhiqfaini, A. (2021). Effectiveness of basic physics practicum in determining gravity acceleration based on virtual mobile observatory. *Kasuari: Physics Education Journal*, *4*(1), 13–20.

Maruf, M., Setiawan, A., Suhandi, A., & Siahaan, P. (2021). Trends in the development of physics learning multimedia in indonesia: a literature review. *Jurnal Pendidikan Fisika*, *9*(3), 185–192. https://doi.org/10.26618/jpf.v9i3.5853

Munawaroh, L. W., Serevina, V., & Iswanto, B. H. (2021). MIX reality based media prototype for learning physics of gravity and Kepler's law. *Journal of Physics: Conference Series*, *2019*(1). https://doi.org/10.1088/1742-6596/2019/1/012054

Paszkiewicz, A., Salach, M., Dymora, P., Bolanowski, M., Budzik, G., & Kubiak, P. (2021). Methodology of implementing virtual reality in education for industry 4.0. *Sustainability (Switzerland)*, *13*(9), 1–25. https://doi.org/10.3390/su13095049

Rojas-Sánchez, M. A., Palos-Sánchez, P. R., & Folgado-Fernández, J. A. (2023). Systematic literature review and bibliometric analysis on virtual reality and education. In *Education and Information Technologies* (Vol. 28, Issue 1). Springer US. https://doi.org/10.1007/s10639-022-11167-5

Suliyanah, Deta, U. A., Kurniawan, F. K., Lestari, N. A., Yantidewi, M., Jauhariyah, M. N. R., & Prahani, B. K. (2021). Literature Review on the Use of Educational Physics Games in Improving Learning Outcomes. *Journal of Physics: Conference Series*, *1805*(1). https://doi.org/10.1088/1742-6596/1805/1/012038