Exploring the Impact of Mobile-Based 3D Simulation on Student's Achievement and Satisfaction in Physics Education

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Abstract. The purpose of this study is to investigate the efficacy of utilizing a mobile-based 3D simulation to support students in the 11th grade in their learning of physics. The precise subject matter that was selected for this piece of research was the equilibrium of rigid bodies. There were 91 students from East Java, Indonesia, included in the sample. This study adopted a quasi-experiment, and the participants were split into two groups: the experimental and control groups. Firstly, a pre-test was given to the students in both groups to see whether or not they came from similar academic backgrounds. Then, students in both groups started their learning by utilizing the mobile application and book, respectively. After completing the learning process, students need to complete a post-test to assess whether or not those who learned using the mobile-based 3D simulation could attain higher scores than those who had learned via books. In addition, this study uses a self-administered questionnaire to determine students' satisfaction with the benefits, simplicity of use, enjoyment, and intention to utilize the application. The results showed that mobile-based 3D simulation improved students' understanding of physics, which led to better grades. Moreover, the students reported the highest levels of satisfaction with the perceived benefit, followed by the ease of use, enjoyment, and the intention to use the mobile-based simulation again in the near future.

Keywords: 3D simulation, satisfaction, physics.

1 Introduction

The rapid growth of technology has had an impact on a variety of fields, one of which is education. Technology in education is becoming an intrinsic component of the learning process. According to [1], information and communication technologies (ICTs) contribute significantly to education in many ways, beginning with preschool and continuing through university. Education with technology support allows learners to learn at their own pace and in a personalized manner. Many applications have been developed to support teachers in delivering knowledge on various topics, such as biology [2, 3], physics [4, 5], mathematics [6, 7], chemistry [8, 9], and language [10, 11].

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Physics is one of the main and important science subjects to be learned by high school students. This field of study involves natural phenomena and how they interact within the universe. Students mostly rely on books as the traditional form of media for their education and participate in experiments to gain a deeper comprehension of real-world natural phenomena. However, students still face difficulty learning physics because books with experiments are not enough to cover all possible phenomena, specifically rigid body equilibrium. This topic focuses on rigid body properties and their kinematics. Students have a hard time imagining the equilibrium system and understanding the formulas. Thus, it is essential to provide the students with a tool that have a clear visualization of kinematics and rigid bodies as well as simulate various kinds of input on existing formulas. Further, regarding scientific literacy, the Program for International Student Assessment (PISA) reported that Indonesia is ranked 70 out of 78 nations participating in the study with a low score of 396 [12].

The development of innovative tools in physics learning, including simulation applications, has increased in recent years. According to [13], a simulation offers students the opportunity to learn in an interactive and personal manner. Further, simulation allows students to manipulate variables, observe the effects of their actions and explore physics concepts more naturally [14]. Based on the platform, the simulation application can be categorized into computer-based and mobile-based. Some authors concluded that computer-based simulation could effectively promote active learning and engagement in physics education [14 - 17].

Mobile-based simulation can be classified as mobile learning, which can be described as the utilization of mobile devices in the educational process [18]. A survey reported that the percentage of mobile phone users in Indonesia reached 65.87 percent in 2021, an increase of around 3% compared to the previous year [19]. In the meantime, it was discovered that 65.34 percent of mobile phone users were in the age bracket of 9-19 years old; this age range includes high school students [20]. Students in high school are members of Generation Z and are known for having grown up with technology readily available to them [21]. As a result, they rely extensively on mobile devices to carry out their educational activities. However, only a few studies have looked into how successful mobile-based simulation might be for high school students, particularly in Indonesia.

In light of the gap, this study proposes the following research questions: R1. Does mobile-based 3D simulation increase students' achievement in learning physics, specifically rigid body equilibrium topics?; R2. What is the level of student satisfaction in using mobile-based 3D simulation in terms of benefits, ease of use, enjoyment, and intention to use?

The findings are intended to contribute to the body of knowledge on the effectiveness of mobile-based 3D simulation usage in learning physics and students' level of satisfaction, especially in Indonesia, which is still very limited. Regarding practical contribution, teachers and mobile application developers may use the findings to understand better the significance of utilizing mobile-based 3D simulation, as a new innovative technology, for students in learning physics. Furthermore, the criteria that were investigated to determine students' level of satisfaction may provide useful insights that mobile application developers may use.

2 Theoretical Background

Traditional teaching and learning methods have evolved to accommodate the new technological landscape by taking advantage of the opportunities presented by newly developed technologies. As a result, numerous innovative educational tools have recently been developed to improve the quality of learning processes, leading to higher students' cognitive levels. Table 1 summarizes various studies investigating how technologies might be utilized in physics education. The studies confirmed that using technologies such as augmented reality (AR), virtual reality (VR), and computer-based simulations can improve student engagement and learning outcomes in various physics topics.

The research on AR highlighted its potential to promote self-efficacy and conceptions of learning in optics [5], magnetism [22, 23], and heat conduction [24]. According to [25], incorporating AR into problem-based learning has shown positive benefits on learning achievement as well as attitudes towards force, movement, and pressure in the classroom. Research that is based on VR analyzes immersive and interactive environments, with studies concentrating on electromagnetics, electrostatics, waves [26, 27], the water cycle in nature [28], and the theory of relativity [29]. These studies illustrated the potential of virtual reality (VR) to develop learning experiences that are both authentic and engaging.

Another technology, computer-based simulations, has offered interactive learning tools for teaching physics, covering topics such as electrical resistance and Ohm's law [30], optics [16], Hooke's and Coulomb's laws, motion, gravitation, energy, and waves [15], electrostatics [14], and electrodynamics [17]. These flexible and accessible simulation platforms provided students with the ability to explore and understand complex concepts.

In addition, the studies have globally demonstrated the potential of technology-enhanced learning approaches in physics education in various countries. However, as listed in Table 1, limited existing research was conducted in the Southeast Asia region.

Table 1. Studies in educational technology for learning physics.

Focus of Study	Topic	Type	Country	Reference
Effects of learning physics using Augmented Reality on students' self-efficacy and conceptions of learning	Optics	AR	China	[5]
The effect of using augmented reality and sensing technology to teach magnetism in high school physics	Magnetism	AR	Turkey	[23]
The effects of augmented reality on learning and cognitive load in university physics laboratory courses	Heat conduction	AR	German	[24]
Integrating augmented reality into PBL: The effects on learning achievement and attitude in physics education	Force, movement, pressure	AR	Turkey	[25]

Applications of augmented reality-based natural interactive learning in magnetic field instruction	Magnetic	AR	China	[22]
Augmented and virtual reality for physics: Experience of Kazakhstan secondary educational institutions	Mechanics, vibrations, waves, molecular physics, thermodynamics	AR and VR	Kazakhstan	[31]
An Interactive and Immersive Virtual Reality Physics Laboratory	Electromagnetic, electrostatic, wave	VR	Austria	[26]
Teaching and learning physics using 3D virtual learning environment: A case study of combined virtual reality and virtual laboratory	Water cycle in nature	VR	Ireland	[28]
The effectiveness of a 3D-virtual reality learning environment	Waves	VR	Oman	[27]
Learning experience design with immersive virtual reality in physics education	Theory of relativity	VR	Cyprus	[29]
Learning physics using interactive simulation	Electrostatics	CBS	South Africa	[14]
Simulations to teach science subjects: Connections among students' engagement, self-confidence, satisfaction, and learning styles	Hooke's and Coulomb's laws, motion, gravitation, energy, waves	CBS	Kuwait	[15]
Effectiveness of PhET simulations to improve the learning of optics	Optics	CBS	Rwanda	[16]
The Effect of Using Computer Simulation on Students' Performance in Teaching and Learning Physics	Electrical resistance and Ohm's law	CBS	Morocco	[30]
Effect of physics education technology (PhET) simulations: evidence from stem students' performance	Electrodynamics	CBS	Philippines	[17]

Notes: *AR = Augmented Reality; VR = Virtual Reality; CBS = Computer-based Simulation*

3 Methodology

This study utilized a quasi-experimental design in order to evaluate the effect of mobile-based 3D simulation on learning outcomes in physics. An innovative new teaching tool was developed in the form of a mobile-based, three-dimensional simulation of the equilibrium of rigid bodies. The 11th-grade students are required to have a working knowledge of this topic. The individuals who agreed to take part in this research were divided into two distinct groups: the experimental and control groups. Before beginning the evaluation, all of the participants in both groups will need to complete a pre-test. This evaluation will ensure that the groups are comparable to one another and will set the baseline measurements.

Following the completion of the pre-test, the group assigned to the experimental learned about physics by using mobile-based 3D simulations, while the group assigned to the control continued to rely on the more conventional method of reading books. After that, it is necessary for both groups to carry out another post-test to ascertain whether the students in the experimental group acquired a deeper comprehension than those in the control group. In addition, the students in the experimental group are expected to fill out the questionnaire to determine their level of satisfaction when using mobile-based 3D animation.

4 Results and Discussion

4.1 Experimental Application

This research used mobile-based 3D simulation as a tool to conduct the investigation. The application provided a three-dimensional simulation of the equilibrium of rigid bodies for 11th-grade students to learn personally and interactively. The contents were developed based on the official reference book as well as the results of interviews conducted with two physics teachers in the 11th grade. Also, in order to get more understanding of the student's difficulties in learning the equilibrium of rigid bodies topic, direct observation was performed during the class session. All simulation features designed in the application were based on the data obtained. Additionally, the application provided several exercises to solve by playing with the simulations.

Unity 5.6 was the piece of software that was utilized during the process of constructing the mobile-based 3D simulation. The contents of the application were then verified by two physics teachers. Finally, the finished application was converted into an Android app, which individual students could download onto their own mobile devices. The 3D simulation application includes a variety of different simulations, one of which is depicted in Fig. 1. In the beginning of this simulation, the application displayed one load placed on one side of the board. Then, different numbers for the weight on the other side can be inputted into the system. A simulation will be shown by the application to determine whether or not the board will remain balanced, fall to the left side, or fall to the right side.

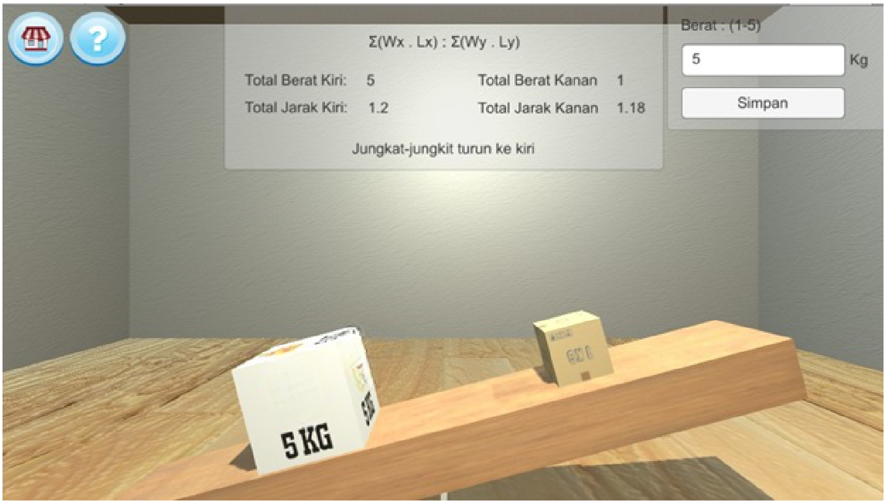

Fig. 1. First Simulation

Meanwhile, Fig. 2 illustrates yet another simulation with which the students can engage in active learning. The second simulation were utilized to calculate the coefficient of friction that exists between the floor and the boards. The very first image that is displayed on the screen depicted a board that is propped up against a wall. In addition, the user was responsible for providing a value for the coefficient of friction, the weight of the board, and the angle at which the board is positioned in relation to the floor. In addition to that, the program will demonstrate in the form of a simulation whether or not the board will slip.

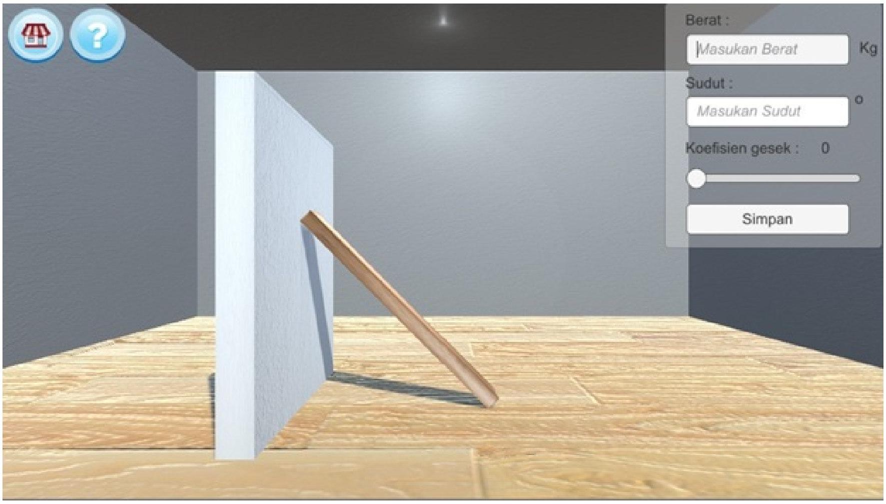

Fig. 2. Second Simulation

4.2 Participants

The total number of participants included in this study was 91 students. All students were in the 11th grade in East Java, Indonesia. The students were split into two groups: experimental and control groups, consisting of 45 and 46 students, respectively. Table 2 contains the demographic information of the respondents for each of the groups.

Table 2. Respondent Profile

Group	Male	Female	Total
Experimental (EG)	24	21	45
Control (CG)	27	19	46
Total	51	40	91

4.3 Pre-test

Firstly, a preliminary test was conducted to ascertain whether the participants possessed the necessary prior knowledge. In addition, the reason for performing a pre-test was to assess the homogeneity of the students and to check that they all had similar knowledge backgrounds. The pre-test questions were selected from numerous reference books on physics, each of which dealt with a specific topic on the equilibrium of rigid bodies. The teachers, as experts, also examined the questions to ensure their validity.

The pre-test scores of precisely two groups were then statistically tested using an independent samples t-test. The results indicated no significant differences between the experimental group and the control group (probability (sig) is 0.341 > 0.05). It means that both groups possessed equivalent levels of skill. Table 3 details the descriptive statistics of the two groups and the independent t-test result.

Table 3. Descriptive statistics and independent t-test (pre-test) result

Group	N	Mean	Std. Deviation	Std. Error Mean	Sig. (2-tailed)
Experimental Group (EG)	45	64.222	10.764	1.605	0.341
Control Group (CG)	46	66.304	9.968	1.470	

4.4 Post-test

After completing the pre-test, students in the experimental group learned the concept of equilibrium of rigid bodies through a mobile-based 3D simulation program. In contrast, students in the control group continued to learn the concept through the use of a book. Every student will be given a post-test at the very end to determine how much they have retained from the lesson. As seen in Table 4, the findings indicate that the mean value of the post-test is greater when compared to the mean value of the pre-test for both groups.

To be more exact, the mean value of the experimental group was greater than that of the control group. Another independent sample t-test was carried out to determine whether the two groups have significantly the same mean. As shown in Table 4, the findings showed that the experimental group had considerably higher levels of learning performance than the control group (probability (sig) is 0.000 < 0.05). The conclusion that can be drawn from this is that increasing students' grasp of physics, particularly with regard to the issue of equilibrium of rigid bodies, by having them learn via mobile-based 3D simulations is beneficial.

Table 4. Descriptive statistics and independent t-test (post-test) result

Group	N	Mean	Std. Deviation	Std. Error Mean	Sig. (2-tailed)
Experimental Group (EG)	45	84.222	9.167	1.367	0.000
Control Group (CG)	46	76.957	7.851	1.158	

4.5 Satisfaction Measurement

The level of student satisfaction with the mobile-based 3D simulation was measured using a questionnaire that the students self-administered. Additionally, the students were asked whether or not they intended to utilize the application in the future. The evaluation was carried out with regard to four different factors: the perceived benefit, the perceived ease of use, the perceived enjoyment, and the intention to use. According to a study by [32], an individual's intention to use technology is mainly determined by their perception of how easy it is to use and how valuable it is. Further, perceived enjoyment has been confirmed can enhance learners' satisfaction in using online video presentations [33].

The questions used for each variable were adapted from those used in previous research to improve the validity and reliability of the results. Table 5 provides the questions on four different variables, along with the reference used. Students in the experimental group used a five-point Likert scale to express their level of agreement of the statements. The scale ranged from 1 (strongly disagree) to 5 (strongly agree).

Table 5. Satisfaction Questionnaire

Variable	Question	Reference
Perceived Enjoyment	PE1. Using mobile-based 3D simulation application is enjoyable. PE2. I have fun using mobile-based 3D simulation application. PE3. I like learning through mobile-based 3D simulation application.	[18]
Perceived Benefit	PB1. I find mobile-based 3D simulation application beneficial. PB2. I find mobile-based 3D simulation application helps me understand the equilibrium of rigid bodies. PB3. I find it easier to understand the equilibrium of rigid bodies using mobile-based 3D simulation application.	[34]

Perceived Ease of Use	PEU1. Mobile-based 3D simulation application is easy to use. PEU2. Mobile-based 3D simulation application is easy to learn. PEU3. Interactions in mobile-based 3D simulation application is easy to understand.	[35]
Intention to use	IU1. I will continue using mobile-based 3D simulation application in the future IU2. I will always try to use mobile-based 3D simulation application in learning equilibrium of rigid bodies. IU3. I plan to continue using mobile-based 3D simulation application frequently.	[36]

The next step is to determine whether or not the obtained data are valid and reliable. Principal component factor analysis was used to investigate the validity of measurement instruments of variables. As seen in Table 6, the findings revealed that the validity of all variables was confirmed to be satisfactory.

Table 6. Validity Results

	Component			
	1	2	3	4
PEU2	.939			
PEU1	.868			
PEU3	.842			
PB3		.924		
PB2		.870		
PB1		.811		
PE2			.888	
PE1			.869	
PE3			.782	
IU1				.862
IU2				.854
IU3				.782

In the meantime, Cronbach's Alpha was utilized to do reliability tests. Following the standards established by [37], all variables have a Cronbach's Alpha coefficient value greater than 0.7. This number represents the lower threshold for an acceptable level of reliability of the data. The values of each variable's Cronbach's Alpha coefficient are presented in Table 7.

Table 7. Result of Reliability test

Variable	Cronbach's Alpha	Interpretation
Perceived Benefit	0,947	Excellent
Perceived Ease of Use	0,900	Excellent
Perceived Enjoyment	0,889	Good
Intention to Use	0,821	Good

The final step was to establish whether the students were satisfied using a simulation application based on the questionnaire results. The satisfaction level of each variable was calculated based on the average value of all questions on each variable. All variables had average values greater than 4.0, as presented in Table 8, which indicated that students were pleased with the benefits, ease of use, enjoyment, and intention to use the mobile-based 3D simulation application. More specifically, the results discovered that the perceived benefit is the most satisfying aspect of the mobile-based 3D simulation program for students. This suggests that students had the perception that using the mobile-based 3D simulation was beneficial to them. In addition, the students believed that the 3D simulation was simple to operate, and they enjoyed using the application. Finally, they agreed to keep utilizing the application.

Table 8. Student's satisfaction

No	Variable	Average
1	Perceived Benefit	4.65
2	Perceived Ease of Use	4.46
3	Perceived Enjoyment	4.31
4	Intention to Use	4.29

5 Conclusion

The purpose of this research is to evaluate the application of mobile-based 3D simulation as an innovative technique to assist students in learning physics, specifically the topic of equilibrium of rigid bodies. The post-test results were analyzed, and the finding discovered that the mobile-based 3D simulation was evident in boosting the students' achievement in learning physics. Additionally, the questionnaire analysis revealed that perceived benefit brought the highest level of pleasure to the students, followed by ease of use, enjoyment, and the intention to utilize the 3D simulation application in the future.

References

1. P. Vlachogianni and N. Tselios, "Perceived usability evaluation of educational technology using the System Usability Scale (SUS): A systematic review," Journal of Research on Technology in Education, pp. 1–18, Feb. 2021, doi: https://doi.org/10.1080/15391523.2020.1867938.
2. Jinsil Hwaryoung Seo, E. Malone, B. Beams, and M. Pine, "Toward Constructivist Approach Using Virtual Reality in Anatomy Education," pp. 343–366, Jan. 2021, doi: https://doi.org/10.1007/978-3-030-61905-3_18.
3. S. Dreimane and L. Daniela, "Educational Potential of Augmented Reality Mobile Applications for Learning the Anatomy of the Human Body," *Technology, Knowledge and Learning*, Jul. 2020, doi: https://doi.org/10.1007/s10758-020-09461-7.
4. D. R. Chetri, "The attitude of 10th-grade students in learning physics," *Journal of Research in Social Sciences and Language*, vol. 2, no. 1, pp. 58-70, 2022.
5. S. Cai, C. Liu, T. Wang, E. Liu, and J. Liang, "Effects of learning physics using Augmented Reality on students' self-efficacy and conceptions of learning," *British Journal of Educational Technology*, Aug. 2020, doi: https://doi.org/10.1111/bjet.13020.
6. C. Rebollo, I. Remolar, V. Rossano, and R. Lanzilotti, "Multimedia augmented reality game for learning math," Multimedia Tools and Applications, Mar. 2021, doi: https://doi.org/10.1007/s11042-021-10821-3.
7. S. Schutera et al., "On the Potential of Augmented Reality for Mathematics Teaching with the Application cleARmaths," Education Sciences, vol. 11, no. 8, p. 368, Jul. 2021, doi: https://doi.org/10.3390/educsci11080368.
8. M. Abdinejad, B. Talaie, H. S. Qorbani, and S. Dalili, "Student Perceptions Using Augmented Reality and 3D Visualization Technologies in Chemistry Education," *Journal of Science Education and Technology*, vol. 30, no. 1, pp. 87–96, Nov. 2020, doi: https://doi.org/10.1007/s10956-020-09880-2.
9. C. Smith and C. J. Friel, "Development and use of augmented reality models to teach medicinal chemistry," *Currents in Pharmacy Teaching and Learning*, vol. 13, no. 8, pp. 1010–1017, Aug. 2021, doi: https://doi.org/10.1016/j.cptl.2021.06.008.
10. Y. Wen, "Augmented reality enhanced cognitive engagement: designing classroom-based collaborative learning activities for young language learners," *Educational Technology Research and Development*, Nov. 2020, doi: https://doi.org/10.1007/s11423-020-09893-z.
11. R. M. Yilmaz, F. B. Topu, and A. Takkaç Tulgar, "An examination of vocabulary learning and retention levels of pre-school children using augmented reality technology in English language learning," *Education and Information Technologies*, Feb. 2022, doi: https://doi.org/10.1007/s10639-022-10916-w.
12. D. D. Wasilah and A. Ismail, "Perceptions of physics teachers and students in Indonesian senior high schools toward the changes of National Examination to Minimum Competency Assessment," *Research in Physics Education*, vol. 1, no. 1, pp. 1-13, 2022.
13. I. M. Astra, H. Nasbey, and A. Nugraha, "Development Of An Android Application In The Form Of A Simulation Lab As Learning Media for Senior High School Students," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 11, no. 5, Aug. 2015, doi: https://doi.org/10.12973/eurasia.2015.1376a.

14. A. A. Ogegbo and U. Ramnarain, "Teaching and learning Physics using interactive simulation: A guided inquiry practice," *South African Journal of Education*, vol. 42, no. 1, pp. 1-9, 2022.
15. F. Almasri, "Simulations to Teach Science Subjects: Connections Among Students' Engagement, Self-Confidence, Satisfaction, and Learning Styles," *Education and Information Technologies*, Feb. 2022, doi: https://doi.org/10.1007/s10639-022-10940-w.
16. K. Ndihokubwayo, J. Uwamahoro, and I. Ndayambaje, "Effectiveness of PhET Simulations and YouTube Videos to Improve the Learning of Optics in Rwandan Secondary Schools," *African Journal of Research in Mathematics, Science and Technology Education*, vol. 24, no. 2, pp. 253–265, May 2020, doi: https://doi.org/10.1080/18117295.2020.1818042.
17. A. N. Yunzal, Jr. and L. F. Casinillo, "Effect of Physics Education Technology (PhET) Simulations: Evidence from STEM Students' Performance," *Journal of Education Research and Evaluation*, vol. 4, no. 3, p. 221, Aug. 2020, doi: https://doi.org/10.23887/jere.v4i3.27450.
18. E. Pramana, "Determinants of the Adoption of Mobile Learning Systems among University Students in Indonesia," *Journal of Information Technology Education: Research*, vol. 17, pp. 365–398, 2018, doi: https://doi.org/10.28945/4119.
19. S. Sadya, "Persentase Pengguna Telepon Genggam RI Capai 64,87% pada 2021", 2022, available at: https://dataindonesia.id/digital/detail/persentase-pengguna-telepon-genggam-ri-capai-6487-pada-2021 (accessed 20 January 2023)
20. N. Adisty, "Mengulik Perkembangan Penggunaan Smartphone di Indonesia", 2022, available at: https://goodstats.id/article/mengulik-perkembangan-penggunaan-smartphone-di-indonesia-sT2LA#:~:text=Penggunaan%20smartphone%20paling%20banyak%20dari,tahun%20sebesar%2050%2C79%20persen. (accessed 20 January 2023)
21. L. Lisana, "Understanding the key drivers in using mobile payment among Generation Z". *Journal of Science and Technology Policy Management*, (ahead-of-print), 2022.
22. S. Cai, F.-K. Chiang, Y. Sun, C. Lin, and J. J. Lee, "Applications of augmented reality-based natural interactive learning in magnetic field instruction," *Interactive Learning Environments*, vol. 25, no. 6, pp. 778–791, May 2016, doi: https://doi.org/10.1080/10494820.2016.1181094.
23. M. S. Abdusselam and H. Karal, "The effect of using augmented reality and sensing technology to teach magnetism in high school physics," *Technology, Pedagogy and Education*, pp. 1–18, May 2020, doi: https://doi.org/10.1080/1475939x.2020.1766550.
24. M. Thees, S. Kapp, M. P. Strzys, F. Beil, P. Lukowicz, and J. Kuhn, "Effects of augmented reality on learning and cognitive load in university physics laboratory courses," *Computers in Human Behavior*, vol. 108, p. 106316, Jul. 2020, doi: https://doi.org/10.1016/j.chb.2020.106316.
25. M. Fidan and M. Tuncel, "Integrating augmented reality into problem-based learning: The effects on learning achievement and attitude in physics education," *Computers & Education*, vol. 142, p. 103635, Dec. 2019, doi: https://doi.org/10.1016/j.compedu.2019.103635.
26. J. Pirker, M. Holly, I. Lesjak, J. Kopf, and C. Gütl, "MaroonVR—An Interactive and Immersive Virtual Reality Physics Laboratory," pp. 213–238, Jan. 2019, doi: https://doi.org/10.1007/978-981-13-8265-9_11.
27. A. Y. Al Amri, M. E. Osman, and A. S. Al Musawi, "The Effectiveness of a 3D-Virtual Reality Learning Environment (3D-VRLE) on the Omani Eighth Grade Students' Achievement and Motivation towards Physics Learning," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 15, no. 05, p. 4, Mar. 2020, doi: https://doi.org/10.3991/ijet.v15i05.11890.

28. D. Bogusevschi, C. Muntean, & G. M. Muntean, “Teaching and learning physics using 3D virtual learning environment: A case study of combined virtual reality and virtual laboratory in secondary school,” *Journal of Computers in Mathematics and Science Teaching*, vol. 39, no. 1, pp. 5-18, Jan. 2020.
29. Y. Georgiou, O. Tsivitanidou, and A. Ioannou, “Learning experience design with immersive virtual reality in physics education,” *Educational Technology Research and Development*, Nov. 2021, doi: https://doi.org/10.1007/s11423-021-10055-y.
30. M. Ben Ouahi, M. Ait Hou, A. Bliya, T. Hassouni, and E. M. Al Ibrahmi, “The Effect of Using Computer Simulation on Students’ Performance in Teaching and Learning Physics: Are There Any Gender and Area Gaps?,” *Education Research International*, vol. 2021, pp. 1–10, Mar. 2021, doi: https://doi.org/10.1155/2021/6646017.
31. Yevgeniya Daineko, Madina Ipalakova, D. Tsoy, Zhiger Zhassulanuly Bolatov, Zhandos Baurzhan, and Yersultanbek Yelgondy, “Augmented and virtual reality for physics: Experience of Kazakhstan secondary educational institutions,” vol. 28, no. 5, pp. 1220–1231, Jul. 2020, doi: https://doi.org/10.1002/cae.22297.
32. F.D. Davis, “Perceived usefulness, perceived ease of use and user acceptance of information technology,” *Management Information Systems Quarterly*, Vol. 13 No. 3, pp. 319-340, 1989.
33. S. Al Natour and C. Woo, “The determinants of learner satisfaction with the online video presentation method,” *Internet Research*, vol. 31, no. 1, pp. 234-261, 2021.
34. H.-P. Lu and Y.-S. Wung, “Applying Transaction Cost Theory and Push-Pull-Mooring Model to Investigate Mobile Payment Switching Behaviors with Well-Established Traditional Financial Infrastructure,” *Journal of theoretical and applied electronic commerce research*, vol. 16, no. 2, pp. 1–21, 2021, doi: https://doi.org/10.4067/s0718-18762021000200102.
35. S. Balouchi and A. A. Samad, “No more excuses, learn English for free: Factors affecting L2 learners intention to use online technology for informal English learning,” *Education and Information Technologies*, Aug. 2020, doi: https://doi.org/10.1007/s10639-020-10307-z.
36. A. A. Alalwan, A. M. Baabdullah, N. P. Rana, K. Tamilmani, and Y. K. Dwivedi, “Examining adoption of mobile internet in Saudi Arabia: Extending TAM with perceived enjoyment, innovativeness, and trust,” *Technology in Society*, vol. 55, pp. 100–110, Nov. 2018, doi: https://doi.org/10.1016/j.techsoc.2018.06.007.
37. D. George and P. Mallery, *SPSS for Windows step by step: A simple guide and reference, 11.0*, 4th ed. Needham Heights, Ma: Pearson Higher Education, 2003.