https://journal.ypidathu.or.id/index.php/jssut/
P - ISSN: 3026-5959
E - ISSN: 3026-605X

Use of Augmented Reality (AR) in Mobile Learning for Natural Science Lessons

Fauzi Erwis[1], Cai Jixiong[2], Novi Rahayu[3], Agung Rachmat Raharja[4], Rony Sandra Yofa Zebua[5]

[1]Universitas Rokania, Indonesia
[2]Universidad Central de Venezuela, Venezuela
[3]Sekolah Tinggi Ilmu Administrasi Bengkulu, Indonesia
[4]Universitas Bandung, Indonesia
[5]Universitas Islam Bandung, Indonesia

ABSTRACT

Background. The development of information technology continues to change from time to time, especially Augmented Reality (AR), which has opened up new opportunities in education by introducing more interactive and interesting learning concepts. In the context of Natural Science (Science) lessons, the use of Augmented Reality in Mobile Learning offers the potential to increase students' understanding of complex concepts through visual and practical-based learning experiences.

Purpose. This research aims to determine the use of Augmented Reality in Mobile Learning for learning Natural Sciences. The focus is to assess the impact of using Augmented Reality on understanding Natural Science concepts, learning motivation, and student engagement.

Method. The research method used in this research is a quantitative method using a random control experiment where two groups of students are divided randomly, one group uses conventional learning methods while the other group uses the Mobile Learning application with Augmented Reality features. Data was collected through a learning motivation questionnaire.

Results. The research results showed that the group that used Augmented Reality in Mobile Learning showed an increase in understanding of Natural Science concepts compared to the control group that used conventional methods. In addition, they also show higher levels of learning motivation and more active involvement in the learning process.

Conclusion. The conclusion of this research is that the use of Augmented Reality in Mobile Learning for learning Natural Sciences has the potential to increase learning effectiveness by providing a more interactive, visual and practical learning experience. The results of this research show that Augmented Reality can be a valuable tool in increasing students' understanding of Natural Science concepts, as well as motivating them to learn better. Therefore, the integration of Augmented Reality in Mobile Learning can be an effective strategy in improving the quality of Natural Sciences education in this digital era.

KEYWORDS

Augmented Reality, Mobile Learning, Natural Science Lessons.

Citation: Erwis, F., Jixiong, C., Rahayu, N., Raharja, R, A. & Zebua, Y, S, R. (2024). Use of Augmented Reality (AR) in Mobile Learning for Natural Science Lessons. *Journal of Social Science Utilizing Technology*, *2*(1), 116–126. https://doi.org/10.70177/jssut.v2i1.784

Correspondence:

Fauzi Erwis,
fauzierwis@gmail.com

Received: March 30, 2024

Accepted: April 3, 2024

Published: April 17, 2024

INTRODUCTION

Technology has become one of the main drivers of change in modern society, influencing almost every aspect of human life (Aju & Mack, 2022). From the way we work,

to communicate, to the way we learn, technology has brough more advanced transformation (Alsubaie, 2022). In this digital era, technological developments are increasingly rapid and innovative, giving us access to various tools and systems that allow us to do things that were previously thought impossible. One of the main trends in technological development is convergence, namely the unification of various technologies and platforms to create more complex and integrated solutions. For example, information and communications technologies (ICT) have become central to many new innovations, such as the Internet of Things (IoT) (Greco dkk., 2020), artificial intelligence (AI) (Ahmad dkk., 2022), and virtual reality (VR) and augmented reality (AR) (Alkhabra dkk., 2023). This convergence enables wider and deeper adoption of technology in various fields, including education.

Education is one of the sectors most influenced by technological developments (Arantes, 2023). From the use of computers in teaching to the adoption of mobile devices and online learning platforms, technology has changed the way we learn and teach. One of the latest innovations that is changing the educational landscape is mobile learning, where learning is carried out via mobile devices such as smartphones or tablets (Aceto dkk., 2019). Mobile learning allows more flexible and easier access to learning materials, enabling learning anywhere and at any time (Criollo-C dkk., 2021). In mobile learning, Augmented Reality (AR) technology has emerged as one of the most promising tools for enhancing the learning experience (Santosa dkk., 2021). AR enables the insertion of virtual objects into the real world, creating immersive and interactive experiences. Using a mobile device's camera and a special application, users can view physical objects around them with additional digital information, animations, or visualizations (Alsubaie, 2022). This opens up a variety of opportunities to increase student engagement and expand their understanding of complex concepts.

The application of Augmented Reality in mobile learning has great potential to bring positive changes in education, especially in Natural Science (Science) lessons (Alqahtani & AlNajdi, 2023). Science is a subject that is often considered complicated and difficult for students to understand because of the many abstract concepts and processes that occur in the universe. By using Augmented Reality, these concepts can be presented visually and interactively, making it easier for students to understand them better (Amin dkk., 2020). Apart from that, Augmented Reality also allows students to carry out interactive simulations, observe natural phenomena directly, and in-depth scientific exploration.

Augmented Reality Technology in Mobile Learning for Natural Science Lessons

Augmented Reality is a technology that combines the real world with virtual elements, creating experiences that enrich and enhance the user's perception of the surrounding environment (Baumann & Arthurs, 2023). In the context of mobile learning for natural sciences, Augmented Reality allows students to explore natural science concepts directly via their mobile devices (Faramarzi & Dayag, 2023). Through the use of special applications or software, students can view virtual objects, simulations, or visualizations integrated with the real world through their cellphone screens. Thus, Augmented Reality allows students to learn about natural phenomena (Faramarzi & Dayag, 2023), biological structures, chemical processes, and much more in a more interactive, visual, and practical way.

In mobile learning for natural sciences, Augmented Reality provides many significant benefits. First of all, AR allows students to see abstract concepts into something more concrete and easy to understand (Bagus Nur Rahma Putra dkk., 2021). For example, students can use Augmented Reality applications to visualize the internal structure of the earth, the structure of human anatomy, or geological processes such as volcanic eruptions (Mokmin & Rassy, 2024). By viewing and interacting directly with these 3D models on their phone screens, students can gain a better understanding of these concepts than just through static images in textbooks.

Apart from that, Augmented Reality also facilitates practical and interactive learning. Students can conduct virtual experiments where they can observe chemical reactions, climate

change, or the interactions of living organisms within an ecosystem without the need to use physical equipment or dangerous materials (Alqahtani & AlNajdi, 2023). This not only makes learning safer, but also allows students to experiment freely without the constraints of time or space. They can learn by trial and error, which is an effective learning approach for understanding natural science concepts.

Utilization of Augmented Reality in Natural Science Lessons

The utilization of Augmented Reality in natural science lessons marks a paradigm shift in education. Augmented Reality, a technology that combines the real world with virtual elements, has opened the door to a more interactive learning experience, presenting natural science concepts in a more engaging and understandable way for students (Zhu dkk., 2020). By utilizing Augmented Reality, teachers can take natural science lessons out of the textbook and enrich students' learning experience through simulation, visualization, and more direct interaction with learning materials (Fidan & Tuncel, 2019).

One of the main benefits of utilizing Augmented Reality in natural science lessons is its ability to visualize abstract concepts into something more concrete and easy to understand (Pellas dkk., 2019). For example, by using Augmented Reality applications, students can see the atomic structure directly on their desk or observe how chemical reactions occur in a real virtual environment (Thees dkk., 2020). Thus, concepts that were previously difficult to understand only through images or text can be presented directly in front of students' eyes, allowing them to better understand how natural phenomena work.

Augmented reality also allows students to learn through practical and interactive experiences (Scavarelli dkk., 2021). They can conduct virtual experiments without having to worry about the risks or costs associated with experimenting in a real laboratory. For example, students can witness the process of photosynthesis in a virtual garden or explore the solar system interactively using Augmented Reality devices (Yip dkk., 2019). This not only makes learning more interesting, but also allows students to be actively involved in the learning process, which can improve their understanding and retention of the subject matter.

Not only that, the utilization of Augmented Reality can also facilitate collaborative learning and communication between fellow students (Chen, 2019). Through the use of Augmented Reality applications that enable collaboration in a virtual environment, students can work together to complete complex tasks or explore natural science concepts together. They can discuss, share ideas, and solve problems together, thus building social and cooperation skills that are important in the learning process.

In addition to providing benefits for students, the use of Augmented Reality can also provide additional support for teachers in delivering learning materials in a more interesting and effective way. Teachers can use Augmented Reality applications to create dynamic and interactive presentations, making learning more fun and engaging for students (Parmaxi & Demetriou, 2020). They can also use Augmented Reality to customize learning according to students' individual learning styles, thus ensuring that each student gets a learning experience that suits their needs.

However, while the utilization of Augmented Reality in natural science lessons offers many benefits, challenges can also arise in implementing this technology in an educational setting. One of the main challenges is the availability of infrastructure and devices required to run Augmented Reality applications (Alzahrani, 2020). Although Augmented Reality technology is growing, there are still some schools that may not have access to the necessary devices or sufficient internet connection to support the use of Augmented Reality in learning. Therefore, efforts need to be made to ensure that this technology is equally accessible to all students.

Educators also need to consider how to integrate the use of Augmented Reality into the existing curriculum. It is important to develop lesson plans that align the use of AR with established learning objectives and ensure that this technology is used as a tool to improve student

understanding and achievement, not as a substitute for actual teacher-student interaction. As such, additional training and support may be required for teachers to effectively utilize Augmented Reality technology in their teaching.

There are several previous research opinions, firstly according to (Rukayah dkk., 2021), with the research title Needs Analysis of Natural Science Learning Media Development with STEAM-Based Augmented Reality in Elementary School. The results of the research state that 1) teachers did not fully know about Augmented Reality media and the STEAM approach, 2) teachers had a good perception of STEAM-based Augmented Reality media, and 3) teachers hope there is a natural science learning media, which can represent material in-depth and interactively, such as videos and animations, where each process is explained in detailed and clear media so that students can understand the material and apply it.

Second, according to (Huang dkk., 2022), the research title Applying Activity System-Based Process Model in Augmented Reality-Based Learning for Natural Science Course in Elementary School, the results of the research state that he learning outcomes and learning attitude of the ARBL group were better than those of the TBL group. The activity system-based process model could provide a helpful structure in the ARBL to guide course designers, teachers, and researchers for designing the AR learning activity.

Third, according to (Flavián dkk., 2019), the research title The impact of virtual, augmented and mixed reality technologies on the customer experience, the results of the research state that allows academics and managers to classify all technologies, current and potential, which might support or empower customer experiences, but can also produce new experiences along the customer journey**.**

RESEARCH METHODOLOGY

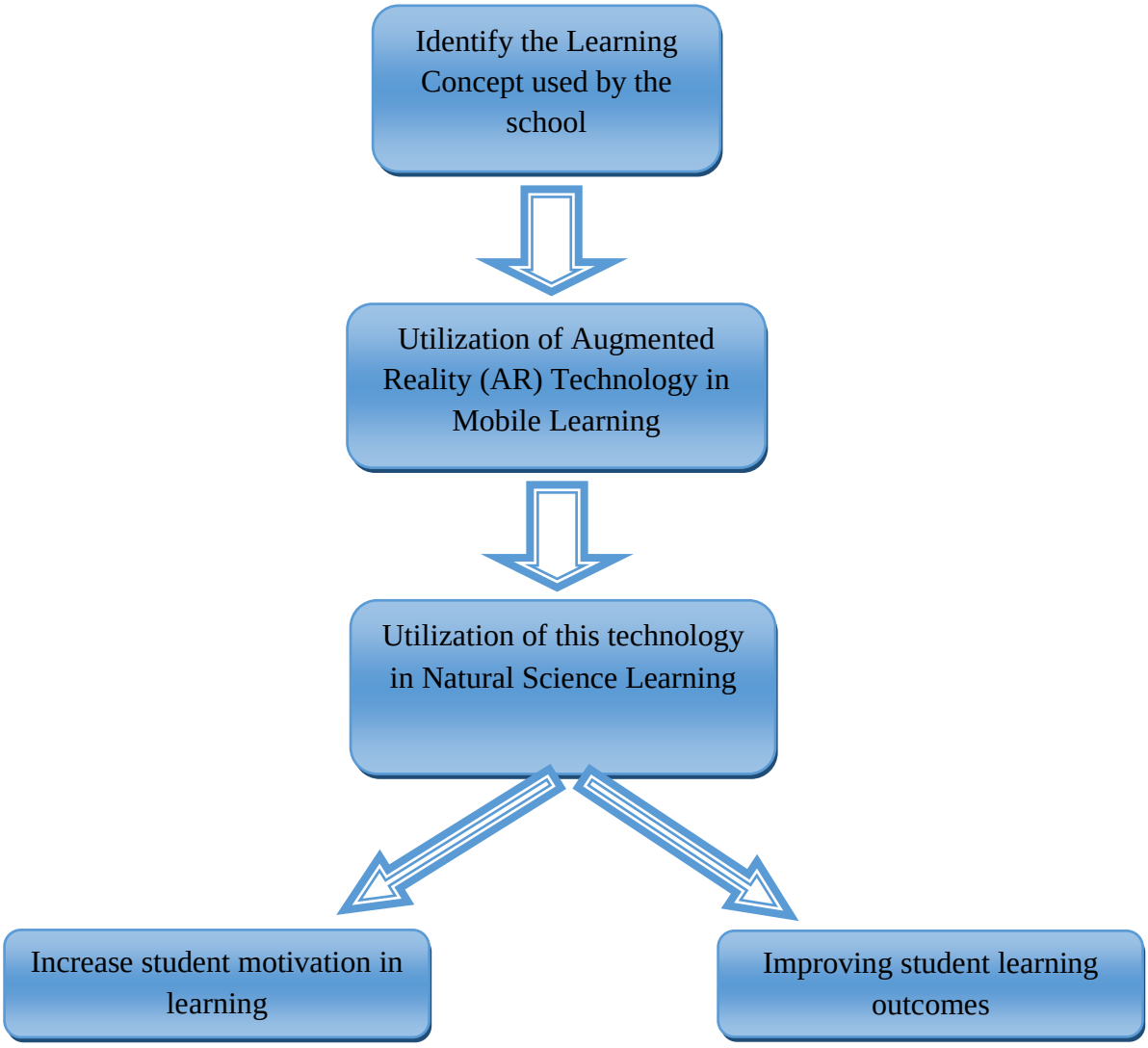
The research method used in this study is a quantitative method using a control experiment. A research method is a series of processes, steps, or procedures used to achieve a goal or solve a problem (Apriliawati, 2020). Methods involve a systematic approach in carrying out certain processes. So the research method is a process or an approach used by researchers to collect and analyze data in order to answer questions in research. The control experimental method is a research approach used to evaluate the impact of a treatment or intervention on an experimental group, compared to a control group that does not receive the same treatment or intervention. In the context of utilizing Augmented Reality in Mobile Learning for Science lessons (Vasilevski & Birt, 2020), the control experiment method is used to compare the effectiveness of learning between students who use Mobile Learning applications with Augmented Reality (experimental group) and students who receive conventional learning (control group).

The research sample is a small part of the population chosen to be observed or tested in a study. This sample is selected with the aim of accurately representing the population as a whole. In many cases, sampling from the population is done because it is not possible or practical to collect data from the entire population under study. Research samples are usually selected by various methods, including random sampling, stratified sampling, cluster sampling, or quota sampling, depending on the purpose of the study and the characteristics of the population under study (Karaki dkk., 2019). The sample for this study will consist of students in secondary schools studying Science subjects. The sample will be randomly selected.

The research population is the entire group of individuals, objects, or events that are the focus of a study. It is the complete set of all relevant units for the research question posed. The importance of the research population is as the basis of the generalization of the research results. In theory, research results obtained from samples are expected to be applied or generalized to the population as a whole. Therefore, the selection of an appropriate and representative population is very important in research, as it will ensure that the results of the study are reliable and applicable

to the wider population. The research population also guides in setting the theoretical framework and research hypotheses, and helps in determining the interpretation of research results. Thus, the population of this study is secondary school students who are studying Natural Science subjects. This population includes students from various backgrounds, grade levels, and academic abilities.

Chart 1. The flow used in this study can be seen in the figure below



The steps in this research are first formulating clear and specific research objectives related to the use of Reality Augmentation in Mobile Learning for Natural Science. This includes identifying the research population, namely students who will be the subject of the study. Second is the selection of Augmented Reality applications and appropriate learning content. Next, the development of Augmented Reality applications and content. The Augmented Reality content developed must be of high quality, interactive, and support students' understanding of the science material being taught (Marcel, 2019). Once the Augmented Reality application and content are ready, the next step is to conduct training for teachers and students. Teachers need to be trained on how to use Augmented Reality applications in learning and how to integrate them into the Natural Science curriculum. Meanwhile, students need to be given training on how to use the Augmented Reality application so that they can utilize it well during the learning process.

Researchers should ensure that the interaction between students and the Augmented Reality technology runs smoothly and supports the learning process. During the learning period, it is important to conduct continuous monitoring and evaluation. The next step is data collection. Data

about is collected using prepared evaluation instruments, such as tests or questionnaires. Once the data is collected, it is analyzed using appropriate statistical analysis methods. Finally, the results of data analysis are evaluated in depth to draw conclusions about the impact of utilizing Augmented Reality in Mobile Learning on understanding science concepts. By following these steps, the research on the utilization of Augmented Reality in Mobile Learning for Science lessons can provide a deep and relevant understanding in the educational context.

RESULT AND DISCUSSION

Augmented Reality is a technology that combines real-world elements with virtual elements, such as images, sound, or text, to create an enriched experience (Yung & Khoo-Lattimore, 2019). The steps in applying Augmented Reality technology in natural science learning begin with setting clear learning objectives, which include improving students' understanding of natural science concepts. Next, the selection of Augmented Reality content that is relevant to the curriculum as well as learning needs becomes key. After that, identification of suitable Augmented Reality applications with technical capabilities and features that support interactive learning. Infrastructure preparation that includes mobile devices, tablets, or specialized Augmented Reality devices, as well as a stable internet connection are important next steps. Training for teachers and students on the use of Augmented Reality apps as well as the integration of Augmented Reality content in learning is necessary to ensure proper understanding of the technology.

Furthermore, the integration of Augmented Reality content in natural science learning should be done in a planned and structured manner, following the curriculum and incorporating Augmented Reality content in learning sessions. Monitor students' use of Augmented Reality and provide feedback to improve their learning experience (Chang dkk., 2019). Continuous evaluation of the effectiveness of using Augmented Reality in natural science learning is also important, making necessary improvements or adjustments to enhance the learning process. By following these steps, the implementation of Augmented Reality technology in natural science learning can be done effectively, enriching students' experience and improving their understanding of the concepts of the universe.

The purpose of implementing Augmented Reality in natural science lessons is to increase students' engagement, understanding, and interest in learning the learning material. Through the use of Augmented Reality technology, students can gain a more interactive and enjoyable learning experience, which allows them to explore natural science concepts directly and deeply. In addition, this goal also includes improving students' ability to visualize and understand abstract concepts, such as atomic structure, geological phenomena, or biological processes, more clearly and concretely. In addition, the application of Augmented Reality in natural science learning aims to stimulate students' creativity, collaboration, and exploration in solving problems and generating new knowledge about the natural world around them. Thus, the main goal of implementing Augmented Reality in natural science lessons is to create a learning experience that captivates, arouses curiosity, and enriches students' understanding.

Table 1. Comparison of students who use Augmented Reality in learning Natural Sciences with students who do not apply Augmented Reality

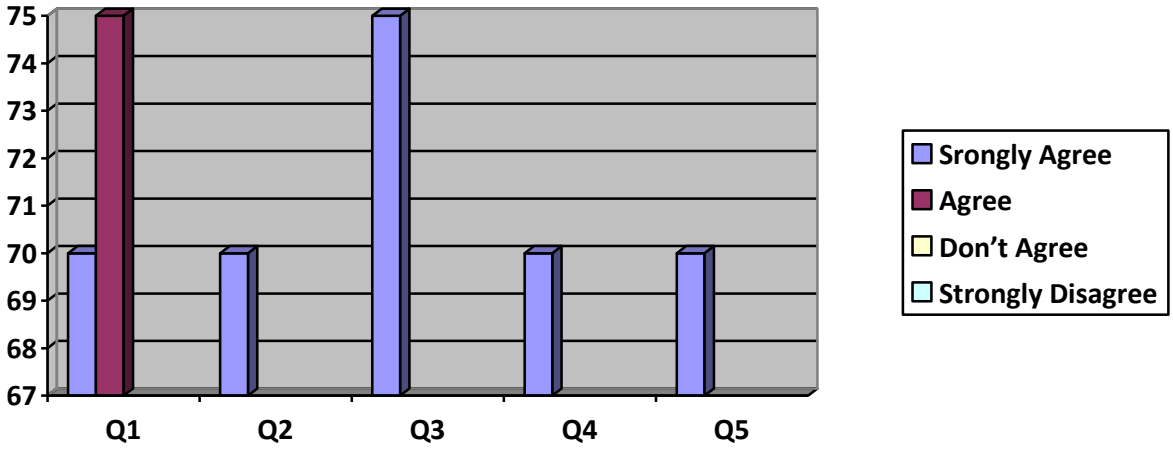
NO	Assessment Aspects	Students who use Augmented Reality				Students who do not use Augmented Reality			
		SA	A	DA	SD	SA	S	DA	SD
1	The level of students' understanding of	70	75						

	material concepts in Natural Sciences lessons has increased.	%	%						
2	Increase students' motivation and interest in studying natural sciences.		70 %						
3	Increased social interaction between peers and student collaboration in learning.		75 %						
4	Create an interactive and interesting learning environment.		70 %						
5	Building a more effective and efficient learning process in natural science learning.		70 %						

Description:
SA=Strongly Agree
S= Agree
DA= Disagree
SD= Strongly Disagree

From the table above it can be understood that students who use Augmented Reality technology in learning Natural Sciences have a positive influence on students compared to students who do not use Augmented Reality technology in learning Natural Sciences. From the table it can be described for the first assessment category, namely the level of students' understanding of material concepts in Natural Sciences lessons has increased obtained responses in the category of strongly agree 70% and agree 75% for students who applied Augmented Reality technology. The second assessment category, namely Increase students' motivation and interest in studying natural sciences obtained responses in the category of agree 70% for students who applied Augmented Reality technology. The third assessment category, namely Increased social interaction between peers and student collaboration in learning obtained responses in the category of agree 75% for students who applied Augmented Reality technology. The fourth assessment category, namely Create an interactive and interesting learning environment obtained responses in the category of agree 70% for students who applied Augmented Reality technology. The fifth assessment category, namely Building a more effective and efficient learning process in natural science learning obtained responses in the category of agree 70% for students who applied Augmented Reality technology.

Diagram of using Augmented Reality



The diagram above is a diagram obtained from the results of the analysis in table 1. The diagram explains that on average, students who use Augmented Reality technology in natural science learning get a positive influence and great feed back for students in increasing students' ability, motivation, monat and way of learning. This is evident from the responses given by students.

Mobile Learning has made an impact on Science learning changing the way students understand and interact with subject matter. One of the main influences of Mobile Learning in Science is increasing accessibility to learning resources (Vasilevski & Birt, 2020). By using mobile devices such as smartphones and tablets, students have instant access to a variety of information resources, applications, and learning content in Science. They can easily look up references, watch video tutorials, or access interactive simulations to support their understanding of scientific concepts. This allows students to learn anytime and anywhere according to their needs, reducing the time and space limitations that usually occur in traditional classroom learning.

In addition to improving accessibility, Mobile Learning also facilitates personalized and adaptive learning. By utilizing technologies such as adaptive learning apps and machine learning algorithms, students can receive learning materials tailored to their needs and level of understanding (Marini dkk., 2022). For example, a Science learning app can automatically adjust the difficulty level of tasks or offer additional materials to deepen the understanding of students who have a special interest in a particular area. As such, Mobile Learning enables a more efficient and effective learning experience, increasing students' potential to achieve higher academic achievement in Science.

The use of mobile devices also provides the opportunity to extend the learning experience through more interactive and engaging media. Many Mobile Learning apps and platforms offer features such as gamification, simulation and augmented reality that allow students to learn through hands-on experience and active engagement. For example, students can use Augmentde Reality apps to virtually explore molecular structures or conduct simulated experiments in a safe and controlled environment. This not only makes learning Science more fun, but also reinforces the understanding of scientific concepts in a more concrete and visual way.

Furthermore, Mobile Learning also promotes collaboration and communication between students and teachers, as well as between fellow students. Through online learning platforms and collaborative apps, students can share ideas, discussions, and projects together in real-time, without being limited by geographical boundaries or class schedules. This creates an inclusive learning environment and supports broader knowledge exchange among learners. In addition, the interaction

that occurs through Mobile Learning also helps to increase students' engagement in Science learning as they feel more involved and have responsibility for their own learning process.

CONCLUSION

The conclusion of this study explains that the utilisation of Augmented Reality in Mobile Learning for Science learning has a positive impact on students. The utilisation of Augmentde Reality also brings great potential to improve learning effectiveness by providing a more interactive, visual and practical learning experience. The results of this study show that Augmented Reality can be a valuable tool in improving students' understanding of Natural Science concepts, as well as motivating them to learn better. Therefore, the integration of Augmented Reality in Mobile Learning can be an effective strategy in improving the quality of Science education in this digital era.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.
Author 4: Formal analysis; Methodology; Writing - original draft.
Author 5: Supervision; Validation.

REFERENCES

Aceto, G., Ciuonzo, D., Montieri, A., & Pescape, A. (2019). Mobile Encrypted Traffic Classification Using Deep Learning: Experimental Evaluation, Lessons Learned, and Challenges. *IEEE Transactions on Network and Service Management*, *16*(2), 445–458. https://doi.org/10.1109/TNSM.2019.2899085

Ahmad, S. F., Alam, M. M., Rahmat, Mohd. K., Mubarik, M. S., & Hyder, S. I. (2022). Academic and Administrative Role of Artificial Intelligence in Education. *Sustainability*, *14*(3), 1101. https://doi.org/10.3390/su14031101

Aju, W., & Mack, V. V. (2022). Automatic Monitoring Technology of Business English Document Translation Equipment Based on Logistic Model. Dalam V. Sugumaran, A. G. Sreedevi, & Z. Xu (Ed.), *Application of Intelligent Systems in Multi-modal Information Analytics* (Vol. 138, hlm. 987–992). Springer International Publishing. https://doi.org/10.1007/978-3-031-05484-6_132

Alkhabra, Y. A., Ibrahem, U. M., & Alkhabra, S. A. (2023). Augmented reality technology in enhancing learning retention and critical thinking according to STEAM program. *Humanities and Social Sciences Communications*, *10*(1), 174. https://doi.org/10.1057/s41599-023-01650-w

Alqahtani, E. S., & AlNajdi, S. M. (2023). Potential obstacles to adopting augmented reality (AR) technologies as pedagogical tools to support students learning in higher education. *Interactive Learning Environments*, 1–10. https://doi.org/10.1080/10494820.2023.2167840

Alsubaie, M. A. (2022). Impacts of Technology in Learning: Mobile Typing Applications for Writing and Accomplishing Academic Tasks among Arabic-Speaking Undergraduate Students. *Education Sciences*, *12*(12), 891. https://doi.org/10.3390/educsci12120891

Alzahrani, N. M. (2020). Augmented Reality: A Systematic Review of Its Benefits and Challenges in E-learning Contexts. *Applied Sciences*, *10*(16), 5660. https://doi.org/10.3390/app10165660

Amin, R. A., Permana, R., & M.Hafizh. (2020). Augmented Reality Introduction to Computer Hardware using Tracking Method in UPI "YPTK" Computer System Labor, Padang. *Jurnal KomtekInfo*, *7*(3), 205–217. https://doi.org/10.35134/komtekinfo.v7i3.81

Apriliawati, D. (2020). Diary Study sebagai Metode Pengumpulan Data pada Riset Kuantitatif: Sebuah Literature Review. *Journal of Psychological Perspective*, *2*(2), 79–89. https://doi.org/10.47679/jopp.022.12200007

Arantes, J. (2023). Educational data brokers: Using the walkthrough method to identify data brokering by edtech platforms. *Learning, Media and Technology*, 1–14. https://doi.org/10.1080/17439884.2022.2160986

Bagus Nur Rahma Putra, A., Mukhadis, A., Ulfatin, N., Anwar Syafrudie, H., Mursyidun Nidhom, A., Ahmad Smaragdina, A., Asari, A., Dzakiya, N., Hasbi Ramadani, A., Bin Md Yunos, J., & Irfano Sembiring, A. (2021). Augmented Reality (AR) Press Machine as the application of the latest learning media technology in the XXI Century. *Journal of Physics: Conference Series*, *1908*(1), 012011. https://doi.org/10.1088/1742-6596/1908/1/012011

Baumann, S., & Arthurs, L. A. (2023). Augmented Reality Technology Used for Developing Topographic Map-Reading Skills in an Earth Science Course and its Potential Implications in Broader Learning Venues. *Journal of Science Education and Technology*. https://doi.org/10.1007/s10956-022-10011-2

Chang, Y.-S., Hu, K.-J., Chiang, C.-W., & Lugmayr, A. (2019). Applying Mobile Augmented Reality (AR) to Teach Interior Design Students in Layout Plans: Evaluation of Learning Effectiveness Based on the ARCS Model of Learning Motivation Theory. *Sensors*, *20*(1), 105. https://doi.org/10.3390/s20010105

Chen, Y. (2019). Effect of Mobile Augmented Reality on Learning Performance, Motivation, and Math Anxiety in a Math Course. *Journal of Educational Computing Research*, *57*(7), 1695–1722. https://doi.org/10.1177/0735633119854036

Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, Á., & Luján-Mora, S. (2021). Mobile Learning Technologies for Education: Benefits and Pending Issues. *Applied Sciences*, *11*(9), 4111. https://doi.org/10.3390/app11094111

Faramarzi, S., & Dayag, J. D. (2023). Augmented Reality and Virtual Reality: New Frontiers in Technology-Enhanced Language Learning. Dalam A. S. Munna, V. Nadda, T. A. Allahyari, G. Cantafio, & S. Bilan (Ed.), *Advances in Educational Technologies and Instructional Design* (hlm. 166–189). IGI Global. https://doi.org/10.4018/978-1-6684-8282-7.ch007

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers & Education*, *142*, 103635. https://doi.org/10.1016/j.compedu.2019.103635

Flavián, C., Ibáñez-Sánchez, S., & Orús, C. (2019). The impact of virtual, augmented and mixed reality technologies on the customer experience. *Journal of Business Research*, *100*, 547–560. https://doi.org/10.1016/j.jbusres.2018.10.050

Greco, L., Percannella, G., Ritrovato, P., Tortorella, F., & Vento, M. (2020). Trends in IoT based solutions for health care: Moving AI to the edge. *Pattern Recognition Letters*, *135*, 346–353. https://doi.org/10.1016/j.patrec.2020.05.016

Huang, C.-Y., Chou, Y.-Y., Chen, C.-H., & Tsai, Y.-H. (2022). Applying Activity System-Based Process Model in Augmented Reality-Based Learning for Natural Science Course in Elementary School. *Mobile Information Systems*, *2022*, 1–18. https://doi.org/10.1155/2022/9579766

Karaki, A., Nasser, A., Jaoude, C. A., & Harb, H. (2019). An Adaptive Sampling Technique for Massive Data Collection in Distributed Sensor Networks. *2019 15th International Wireless Communications & Mobile Computing Conference (IWCMC)*, 1255–1260. https://doi.org/10.1109/IWCMC.2019.8766469

Marcel, F. (2019). Mobile augmented reality learning objects in higher education. *Research in Learning Technology*, *27*(0). https://doi.org/10.25304/rlt.v27.2133

Mokmin, N. A. M., & Rassy, R. P. (2024). Review of the trends in the use of augmented reality technology for students with disabilities when learning physical education. *Education and Information Technologies*, *29*(2), 1251–1277. https://doi.org/10.1007/s10639-022-11550-2

Parmaxi, A., & Demetriou, A. A. (2020). Augmented reality in language learning: A state-of-the-art review of 2014–2019. *Journal of Computer Assisted Learning*, *36*(6), 861–875. https://doi.org/10.1111/jcal.12486

Pellas, N., Fotaris, P., Kazanidis, I., & Wells, D. (2019). Augmenting the learning experience in primary and secondary school education: A systematic review of recent trends in augmented reality game-based learning. *Virtual Reality*, *23*(4), 329–346. https://doi.org/10.1007/s10055-018-0347-2

Rukayah, R., Daryanto, J., Atmojo, I. R. W., Ardiansyah, R., & Saputri, D. Y. (2021). Needs Analysis of Natural Science Learning Media Development with STEAM-Based Augmented Reality in Elementary School. *ICLIQE 2021: Proceeding of The 5th International Conference on Learning Innovation and Quality Education*, 1–4. https://doi.org/10.1145/3516875.3516935

Santosa, I., Nurkhamidah, N., & Wulandari, R. (2021). Identifying The Criteria of Designing Augmented Reality for Vocabulary Learning in Primary School. *JISIP (Jurnal Ilmu Sosial dan Pendidikan)*, *5*(4). https://doi.org/10.58258/jisip.v5i4.2634

Scavarelli, A., Arya, A., & Teather, R. J. (2021). Virtual reality and augmented reality in social learning spaces: A literature review. *Virtual Reality*, *25*(1), 257–277. https://doi.org/10.1007/s10055-020-00444-8

Thees, M., Kapp, S., Strzys, M. P., Beil, F., Lukowicz, P., & Kuhn, J. (2020). Effects of augmented reality on learning and cognitive load in university physics laboratory courses. *Computers in Human Behavior*, *108*, 106316. https://doi.org/10.1016/j.chb.2020.106316

Vasilevski, N., & Birt, J. (2020). Analysing construction student experiences of mobile mixed reality enhanced learning in virtual and augmented reality environments. *Research in Learning Technology*, *28*(0). https://doi.org/10.25304/rlt.v28.2329

Yip, J., Wong, S.-H., Yick, K.-L., Chan, K., & Wong, K.-H. (2019). Improving quality of teaching and learning in classes by using augmented reality video. *Computers & Education*, *128*, 88–101. https://doi.org/10.1016/j.compedu.2018.09.014

Yung, R., & Khoo-Lattimore, C. (2019). New realities: A systematic literature review on virtual reality and augmented reality in tourism research. *Current Issues in Tourism*, *22*(17), 2056–2081. https://doi.org/10.1080/13683500.2017.1417359

Zhu, M., Sun, Z., Zhang, Z., Shi, Q., He, T., Liu, H., Chen, T., & Lee, C. (2020). Haptic-feedback smart glove as a creative human-machine interface (HMI) for virtual/augmented reality applications. *Science Advances*, *6*(19), eaaz8693. https://doi.org/10.1126/sciadv.aaz8693