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Systematic literature review: Effectiveness of augmented reality in mathematics learning for students in Indonesia

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Abstract: The concept of learning media can be understood as a tool used as an intermediary between instructors and students during the learning process. The primary purpose of this tool is to provide information and channel messages, thus enabling effective and efficient learning. The aim of this study is to conduct a comprehensive literature review on the use of Augmented Reality (AR) as a form of learning media in the context of mathematics education. The research methodology employed in this study is the Systematic Literature Review (SLR) approach, which aims to identify, examine, evaluate, and interpret relevant articles. The data collection process involved documenting all articles that were similar in nature to the current research report. The study utilized a total of 20 articles, sourced from both national and international journals, which were retrieved from the Google Scholar database. The findings of the research indicate that the use of Augmented Reality as a learning medium can be beneficial and well-suited for learning mathematics, as it has the potential to improve learning outcomes and enhance students' mathematical capabilities..

INTRODUCTION

Science and Technology plays a pivotal role across all domains, including the social, health, economic, and particularly the educational spheres. Technological advancements have become increasingly sophisticated over the years, driven by the innovative and creative thinking of humans. The development of IPTEK within the field of education itself is exemplified by the utilization of technologies which serve as tools to facilitate the teaching and learning process between educators and students. In line with this perspective, Khairunnisa and Azis (2021) posit that the integration of technology in learning involves spontaneously connecting the activities conducted during instruction with technology-based media. However, the reality on the ground indicates that teachers still predominantly utilize learning media in the form of textbooks or student worksheets, as these resources are perceived to be the easiest to create and use (Sudrajad, et al., 2013). Yet, when considering the advancements, textbooks or LKPD are deemed inadequate in meeting the needs of both teachers and students. The difficulties encountered by students in reading and comprehending the content presented in textbooks are

often attributed as a contributing factor to their boredom during lessons (Suganda and Fahmi, 2020). Therefore, there is a pressing need for learning media that can assist students in understanding the subject matter and visualizing the forms of mathematical constructs.

According to Khotimah and Satiti (2019), one of the rapidly evolving technologies today is the smartphone. Smartphone ownership has become ubiquitous across various demographic groups, and it is safe to assume that students also possess at least one smartphone, if not more. As the number of students owning and using smartphones increases, so too does the potential for leveraging technology in the field of education. One such technology that can support the teaching and learning of mathematics while utilizing smartphones is Augmented Reality (AR) technology. The advantages of utilizing AR-based learning media include assisting teachers in delivering content, reducing time, and creating an interactive and enjoyable learning environment (Afifi, et al., 2021).

Augmented Reality (AR) possesses characteristics that make it an interactive and seemingly realistic learning medium that directly engages students (Nurhaliza, et al., 2022). The emergence of virtual AR objects can help users (students) interact directly with the objects being studied. Additionally, AR technology can be readily accessed through smartphones. Another characteristic of AR is its ability to serve as a link between the virtual and physical worlds, facilitating significant interactions between the two realms, and enabling the display of 3D objects (Kartini, et al., 2020). According to Afifi, et al. (2021), the use of appropriate learning media is expected to reduce the level of abstraction in course content, pique students' interest in learning, and enhance student learning outcomes.

In the 21st century, education should leverage various technologies in the learning process, such as AR technology systems. Building on this premise, the current research aims to explore the use of Augmented Reality in mathematics education. A similar study by Meilindawati, et al. (2023) examined the application of Augmented Reality (AR) learning media in mathematics instruction. However, their discussion was limited to the implementation aspect of AR in mathematics learning. Considering the findings from previous research, this study seeks to expand the exploration by examining the common content, instructional models, objectives, and research methodologies employed by other researchers in the field of using AR in mathematics education

METHODE

The results of the analysis of articles that discuss the use of AR in mathematics learning can be seen in Table 2.

Table 2. Analysis of Article

No.	Author	Methode	Result
1	Afifi, F. C., Chrisnawati, H. E., & Kuswardi, Y. (2021)	R&D	Produce an android-based application called ARGO. The material presented is flat-sided space. The application is suitable for use and has been tested by media experts. Furthermore, from the statistical test results, the average score of

			experimental class students is better than the average score of control class students.
2	Arifin, A. M., Pujiastuti, H., & Sudiana, R. (2020)	R&d	Produce android-based media called ARTIC. The application is effective, practical, and feasible to use and has been tested by media experts and education experts.
3	Billa, S R. F. ., & Siregar, T. M. . (2022)	R&D	The learning media developed in this study are included in the valid, practical and effective categories. Proven by the results of classical learning completeness of 86.6% and the results of student response questionnaires of 94.3%.
4	Farisi, O. I. R., & Pratamasunu, G. Q. O. (2018)	R&D	The developed application is feasible to use as learning media, especially on the material of the nets of cubes and beams. This is the result of testing conducted by media experts, material experts and users.
5	Hanan, R. A., Fajar, I., Pramuditya, S. A., & Noto, M. S. (2018)	Qualitative	Augmented reality is one of the products of renewal of mathematics teaching materials. Especially in the material of building space. Because AR media is able to display more interesting three-dimensional objects.
6	Hardiyanti, D., Rosyadi, R., & Mellawaty, M. (2020)	Qualitative	Three-dimensional learning media on cube and beam material can make students more interested and more active because students are invited to learn while playing.
7	Kartini, K., Sudirman, S., & Lestari, W. D. (2020)	Qualitative	The results of this study are that in learning extroverted students are more active than introverted students. The advantage of extroverted students is that they tend to group activities so that the results of the discussions obtained are better. Meanwhile, the advantage of introverted students is that the results of tests conducted individually are greater because students are more detailed in working on problems.
8	Khotimah, K., & Satiti, W. S. (2019)	R&D	The results of Augmented Reality-based learning media tests on flat-sided space building materials are very valid and effective. With the use of learning media, students show a positive response and are able to achieve learning completeness criteria.
9	Kustiyowati, K., & Pradana, P. H. (2022)	Qualitative	After students operate the Augmented Reality learning media, there are some obstacles such as students who are still rigid in how to operate the

			media because they are not used to using Augmented Reality learning media, so they need extra assistance when operating it.
10	Larasati, N. I., & Widyasari, N. (2021)	Quantitative	AR learning media can improve students' mathematical understanding ability, but there is no significant difference in students' learning styles.
11	Nurwijaya, S. (2022)	Quantitative	Through descriptive statistics, the average pretest of the experimental class is greater than the control class, the average posttest of the experimental class is greater than the control class. In addition, there is an increase in students' sapsial abilities. Therefore, the problem-based learning model with the help of augmented reality has an effect on students' spatial abilities.
12	Pambudi, K. H. B., Buchori, A., & Aini, A. N. (2018)	R&D	Based on the results of statistical tests, it was found that the learning outcomes of students who learned using AR were better than those of students who learned using conventional methods.
13	Pramuditya, S. A., Pitriayana, S., Subroto, T., & Wafiqoh, R. (2022)	Qualitative	The results showed that the AR application has the advantage of being able to help students in understanding and solving questions about three-dimensional space building material. And can improve students' spatial abilities
14	Saputri, S., & Sibarani, A. J. (2020)	R&D	The development of learning media in the form of marker augmented reality based on android is feasible to use for learning. The application functions well, namely it can scan, remove image objects even in low light conditions, and reflect image objects as far as 50cm.
15	Sudirman, S., Kusumah, Y. S., & Martadiputra, B. A. P. (2021)	Mix Methode	Augmented reality blended learning facilitates the understanding of 3D geometry material knowledge by prospective teachers, can increase motivation and learning attitudes, especially in covid-19 conditions.
16	Suganda, M. S., & Fahmi, S. (2020)	R&D	From the results of the assessment by material experts and media experts, the learning media developed received a very feasible assessment for use. Thus, the results of student responses in the experimental class are better than the control class.
17	Sungkono, S., Apiati, V., & Santika, S. (2022)	R&D	Produce an android-based application called GEO3DAR. The material presented is the surface area of the pyramid. The application is suitable for use and has been tested by media experts.

18	Suwito, A., Astuti, N. I., Sunardi, S., & A'yun, Q. . (2023)	Qualitative	As a result, teachers feel that they have new knowledge about learning media and students become active in learning.
19	Waliyansyah, R., Handayanto, A., & Setyawan, B. (2020)	R&D	Produce an android-based application called BARISDA. The material presented is flat-sided space. The application is suitable for use and has been tested by media experts. Furthermore, from the results of the questionnaire, the media is proven to increase student interest in learning
20	Widiadnyana, P., Wiharta, D. M., & Oka Widyantara, I. (2021)	Quantitative	The application of the REACT strategy assisted by AR applications on building space material can improve student learning outcomes.

The method employed in this research is the SLR (Systematic Literature Review) approach. The steps involved in this method include identifying, examining, evaluating, and interpreting all available research. The SLR method is carried out through a systematic review and identification of articles, adhering to the established stages in each process (Triandini, et al., 2019).

The first step is to establish a Research Question or set of research questions based on the needs and focus of the chosen topic. In this study, the Research Questions (RQ) include: (RQ1) What are the objectives and types of research used in articles on the use of AR learning media in mathematics education from 2018-2023?; (RQ2) What are the materials and learning models used to support the learning process in articles on the use of AR learning media in mathematics education from 2018-2023?.

The second step is the Search Process. In this phase, the search process is utilized to obtain relevant sources that can address the Research Questions (RQ) and reference the quality assessment criteria. The researchers gathered articles to complement the study through the Google Scholar database, using the keywords "use of Augmented Reality in mathematics learning".

The third step is the inclusion and exclusion criteria. This stage involves making decisions on whether the data found is suitable for use in the SLR research or not. In this study, studies are deemed eligible for selection if they meet the following criteria:

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Relevant national or international articles related to the use of augmented reality in mathematics learning	National or international articles that are not relevant to the use of augmented reality in mathematics learning
The time span used is articles published in 2018-2023	The time range used is articles published before 2018
Articles obtained from Google Schoolar	Articles obtained other than Google Schoolar

The fourth step is the Quality Assessment. The data obtained will then be evaluated based on the assessment criteria, which include: (QA1) Does the article clearly state the objectives and types of research on the use of AR learning media in mathematics education from 2018-2023?; (QA2) Does the article outline the materials and learning models used to support the learning process in the use of AR learning media in mathematics education from 2018-2023?

RESULT AND DISCUSSION

The analysis summarized in Table 1 provides insights that address the Research Questions (RQ) of this study.

RQ1. What are the objectives and types of research used in articles on the use of AR learning media in mathematics education from 2018-2023?.

A total of 20 articles were obtained through the search process. To answer the question of (RQ1), obtained in Figure 1 below, shows research in 2018-2023 regarding the use of AR learning media in learning mathematics there are differences in research focus.

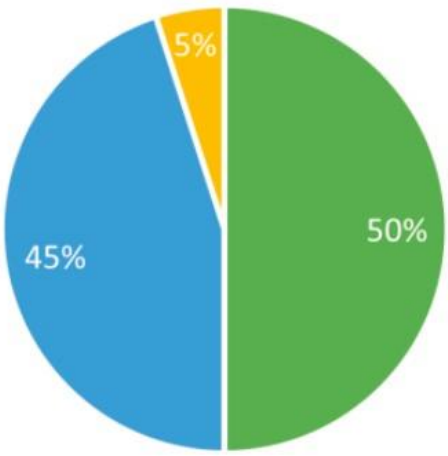

Figure 1. Research Purpose

In Figure 1, there are 3 research focuses found from 20 articles, namely, the focus of research to produce AR-based learning media shows a percentage of 50%, then the focus of

research to implement AR-assisted learning media shows a percentage of 45%, and the last research focus to determine the effect of the application of AR learning media on students' mathematical abilities shows a percentage of 5%. It can be concluded that research in 2018-2023 on the use of AR learning media in learning mathematics tends to focus on producing AR-based learning media.

Furthermore, obtained in Figure 2, shows from 20 articles there are 4 types of research used in the use of AR learning media in mathematics learning in 2018-2023. Research and Development or R&D type research with a percentage of 50% shows that this type of research tends to be more widely used in research on the use of AR learning media in learning mathematics. Furthermore, qualitative research with a percentage of 30%, quantitative research with a percentage of 15%, and mixed method research with a percentage of 5%.

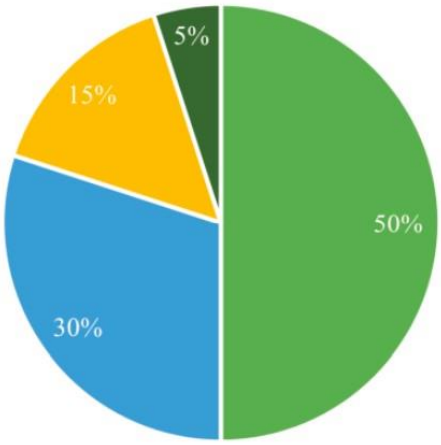

Figure 2. Type Research

(RQ2) What are the materials and learning models selected in the article on the use of AR learning media in mathematics learning in 2018-2023?

Figure 3 illustrates the learning materials used in research on the use of AR learning media in mathematics learning. Mathematics learning materials derived from the 20 articles analyzed are divided into 4 educational units, namely for elementary, junior high, high school, and college materials. The figure shows that the learning material that tends to be used is three-dimensional geometry in articles on the use of AR learning media in learning mathematics in 2018-2023.

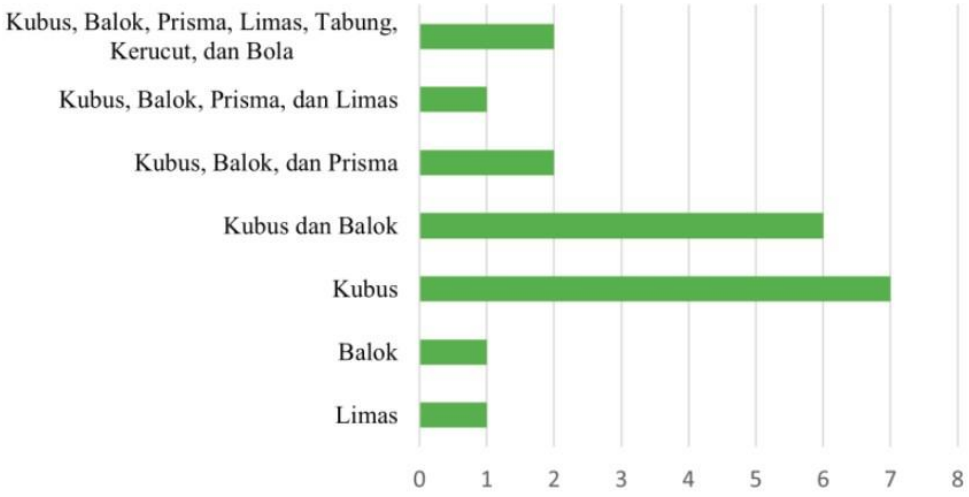

Figure 3. Learning Instrument

Figure 4 illustrates the learning model used in research on the use of AR learning media in mathematics learning. The figure shows that conventional learning models assisted by AR learning media tend to be used in research published in 2018-2023. Learning models that encourage students to be directly involved have a positive impact on student learning outcomes.

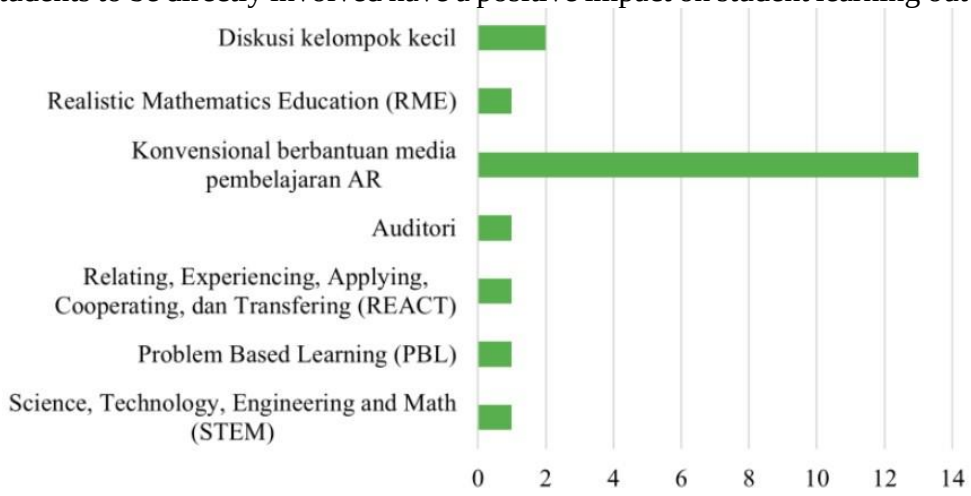

Figure 4. Learning Model

The selection of the use of learning media needs to consider the factors of relevance, feasibility, and convenience (Nurhaliza, et al., 2022). One technology that can be used in learning mathematics is the use of Augmented Reality. The use of Augmented Reality is very useful as an interactive and real learning media used directly by students. The use of learning media such as Augmented Reality has an impact on different learning experiences for students, so that students can gain relevant and broader knowledge, it is also to realize meaningful learning carried out by students because it is supported by the use of technology-based learning media.

Research conducted by Pambudi, et al (2018); Afifi, et al (2021); Khotimah and Satiti (2019); Suganda and Fahmi (2020); Waliyansyah, et al (2020) AR applications are technology-based learning media that have an effect on improving students' cognitive and affective abilities, especially in mathematics. Research conducted by Nurwijaya (2022); Larasati and Widyasari (2021); Arifin, et al (2020) found that technological applications in the form of Augmented Reality have the opportunity to improve students' mathematical spatial abilities and students' mathematical understanding abilities.

CONCLUSION

Based on the results and discussion from the review of 20 articles published between 2018-2023, it can be concluded that the research methods that tend to be used for research on the use of augmented reality media are the development or research and development (R&D) methods. Meanwhile, the materials most commonly used are flat-sided spatial structures. The learning models that tend to be frequently used are the contextual model. The use of augmented reality learning media is good and effective in assisting mathematics learning, as it can improve learning outcomes and enhance students' spatial mathematical abilities.

REFERENCE

Afifi, F. C., Chrisnawati, H. E., & Kuswardi, Y. (2021). Pengembangan Media Pembelajaran Argo (Augmented Reality Of Geometric Objects) Pada Materi Bangun Ruang Sisi Datar Di SMP Negeri 3 Batang. *Jurnal Pendidikan Matematika dan Matematika SOLUSI, 5*(6), 271-280.

Arifin, A. M., Pujiastuti, H., & Sudiana, R. (2020). Pengembangan media pembelajaran STEM dengan augmented reality untuk meningkatkan kemampuan spasial matematis siswa. *Jurnal Riset Pendidikan Matematika, 7*(1), 59-73. http://dx.doi.org/10.21831/jrpm.v7i1.32135.

Billa, S R. F. ., & Siregar, T. M. . (2022). Pengembangan media pembelajaran berbasis web google sites berbantuan augmented reality untuk meningkatkan hasil belajar siswa pada materi bangunruang sisi datar. *Humantech : Jurnal Ilmiah Multidisiplin Indonesia, 2*(2), 294–302. https://doi.org/10.32670/ht.v2i2.2803

Farisi, O. I. R., & Pratamasunu, G. Q. O. (2018). Mobile Augmented Reality sebagai media pembelajaran interaktif jaring-jaring kubus dan balok. *NJCA (Nusantara Journal of Computers and Its Applications), 3*(2), 96-104.

Hanan, R. A., Fajar, I., Pramuditya, S. A., & Noto, M. S. (2018). Desain Bahan Ajar Berbasis Augmented Reality pada Materi Bangun Ruang Bidang Datar. In *Prosiding Seminar Nasional Matematika dan Pendidikan Matematika (SNMPM), 2*(1), 287-299.

Hardiyanti, D., Rosyadi, R., & Mellawaty, M. (2020). Implementasi Augmented Reality (AR) untuk membantu siswa belajar geometri dimasa pandemi di SMPN 1 Sindang. *Integral: Pendidikan Matematika, 11*(2), 40-50.

Kartini, K., Sudirman, S., & Lestari, W. D. (2020). Pembelajaran Geometri Berbantuan Aplikasi Mobile Augmented Reality Pada Siswa Ekstrovert Dan Introvert. *Jurnal Edukasi Dan Sains Matematika (JES-MAT), 6*(2), 139-156. https://doi.org/10.25134/jes-mat.v6i2.2709.

Khairunnisa, S., & Aziz, T. A. (2021). Studi Literatur: Digitalisasi Dunia Pendidikan dengan Menggunakan Teknologi Augmented Reality pada Pembelajaran Matematika. *Jurnal Riset Pendidikan Matematika Jakarta, 3*(2), 53-62. https://journal.unj.ac.id/unj/index.php/jrpmj/article/view/20106.

Khotimah, K., & Satiti, W. S. (2019). Pengembangan Media Pembelajaran Berbasis Augmented Reality Pada Materi Bangun Ruang Sisi Datar Kelas VIII. *Prosiding Seminar Nasional Multidisiplin, 2*(1), 99–105. Retrieved from https://ejournal.unwaha.ac.id/index.php/snami/article/view/675.

Kustiyowati, K., & Pradana, P. H. (2022). Pemanfaatan Augmented Reality Untuk Materi Bangun Ruang Sisi Datar Untuk SMP/MTS. *Jurnal IKA PGSD (Ikatan Alumni PGSD) UNARS, 10*(2), 141-150. https://doi.org/10.36841/pgsdunars.v10i2.1446.

Larasati, N. I., & Widyasari, N. (2021). Penerapan media pembelajaran berbasis augmented reality terhadap peningkatan pemahaman matematis siswa ditinjau dari gaya belajar. *FIBONACCI: Jurnal Pendidikan Matematika dan Matematika, 7*(1), 45-50. https://doi.org/10.24853/fbc.7.1.45-50.

Meilindawati, R., Zainuri, Z., & Hidayah, I. (2023). Penerapan media pembelajaran augmented reality (ar) dalam pembelajaran matematika. *JURNAL e-DuMath, 9*(1), 55-62. https://doi.org/10.52657/je.v9i1.1941.

Nurhaliza, S. M., Mudrikah, A., & Hakim, L. L. (2022). Peningkatan Hasil Belajar Peserta Didik melalui Penerapan Media Pembelajaran Geometry with Augmented Reality (GO-AR). *PRISMA, 11*(2), 467-477.

Nurwijaya, S. (2022). Pengaruh Model Pembelajaran Problem Based Learning Berbantuan Augmented Reality Terhadap Kemampuan Spasial Siswa. *EQUALS: Jurnal Ilmiah Pendidikan Matematika, 5*(2), 107-116. https://doi.org/10.46918/equals.v5i2.1563.

Pambudi, K. H. B., Buchori, A., & Aini, A. N. (2018). Pengembangan media pembelajaran berbasis android menggunakan augmented reality pada materi bangun ruang sisi datar. *Jurnal Pendidikan Matematika dan Sains*, 6(1), 61-69.

Pramuditya, S. A., Pitriayana, S., Subroto, T., & Wafiqoh, R. (2022). Implementation of augmented reality-assisted learning media on three-dimensional shapes. *Jurnal Elemen*, 8(2), 480-493.

Saputri, S., & Sibarani, A. J. (2020). Implementasi augmented reality pada pembelajaran matematika mengenal bangun ruang dengan metode marked based tracking berbasis android. Komputika: *Jurnal Sistem Komputer*, 9(1), 15-24.

Sudirman, S., Kusumah, Y. S., & Martadiputra, B. A. P. (2021). Augmented reality blended learning instruction: the impact on growing motivation, attitudes, and knowledge in 3D geometry. *Turkish Journal of Computer and Mathematics Education*, 12(4), 674-683.

Suganda, M. S., & Fahmi, S. (2020). Pengembangan Media Pembelajaran Berbasis Augmented Reality pada Materi Bangun Ruang Sisi Datar. *THETA: Jurnal Pendidikan Matematika*, 2(2), 50-57.

Sungkono, S., Apiati, V., & Santika, S. (2022). Media Pembelajaran Berbasis Teknologi Augmented Reality. *Mosharafa: Jurnal Pendidikan Matematika*, 11(3), 459-470.

Suwito, A., Astuti, N. I., Sunardi, S., & A'yun, Q. . (2023). Implementasi Augmented Reality dalam Pengajaran Mata Pelajaran Matematika di SDN Rambigundam 1. *Jurnal Altifani Penelitian Dan Pengabdian Kepada Masyarakat*, 3(2), 223–227. https://doi.org/10.59395/altifani.v3i2.370.

Triandini, E., Jayanatha, S., Indrawan, A., Werla Putra, G., & Iswara, B. (2019). Metode Systematic Literature Review untuk Identifikasi Platform dan Metode Pengembangan Sistem Informasi di Indonesia. *Indonesian Journal of Information Systems*, 1(2), 63–77. https://doi.org/10.24002/ijis.v1i2.1916.

Waliyansyah, R., Handayanto, A., & Setyawan, B. (2020). Aplikasi Pembelajaran Bangun Ruang Sisi Datar (Barsida) Menggunakan Augmented Reality (AR) Berbasis Android. *Journal of Informatics Information System Software Engineering and Applications (INISTA)*, 3(1), 1-12. https://doi.org/10.20895/inista.v3i1.131.

Widiadnyana, P., Wiharta, D. M., & Oka Widyantara, I. (2021). Penerapan strategi react berbantuan augmented realuty bangun ruang terhadap hasil belajar matematika. *Journal of Syntax Literate*, 69(12). 10.36418/Syntax-Literate.v6i12.3007.