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Development of Augmented Reality (Ar)-Based Interactive Digital Magazine Media for Class X Chemistry Bond Learning

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Abstract

Technological advancements demand innovation in learning media, particularly in the digital era. Chemistry lessons, such as those on chemical bonds, are often considered abstract and difficult for students to grasp. Therefore, engaging, interactive, and contextual learning media are needed. The use of interactive digital magazines based on Augmented Reality (AR) is expected to enhance conceptual understanding and student learning interest. The study successfully developed and tested an AR-based interactive digital magazine for teaching atomic bonding to Grade X learners, yielding highly positive results in terms of validity, effectiveness, and user satisfaction. The media achieved a validity score of 95.10% for material and 95.00% for media aspects, with an N-Gain score of 0.7964 indicating high effectiveness. Additionally, teacher practicality was rated at 93.74%, and learner responses reached 89.75%, both rated as very high, confirming the media's feasibility and effectiveness for studying atomic bonding concepts.

Keywords: Augmented reality; chemistry bond; digital magazine; interactive media

Introduction

Chemistry was one of the branches of natural science that played an important role in explaining natural phenomena and supporting the advancement of modern technology. However, in practice, studying chemistry was often considered difficult by learners because it contained abstract and complex concepts (Rahayu et al., 2024). Educators were able to create content and design the material to be taught or share information with the public (Junaidi et al., 2024). The Android platform played an important role in the development of learning media, as it allowed for easily accessible, flexible technology integration and supported the presentation of material in an interactive and engaging manner for students (Sari et al., 2021). One of the materials that was a big challenge was atomic bonding, which required a deep understanding and the ability to visualise microscopic processes (Simanjuntak & Purba, 2024). Learners' understanding of chemistry material was still low because they found it difficult to learn chemistry.

Chemical bonds explained how atoms bind to each other to form molecules. This concept served as the basis for understanding other chemical materials, such as the structure of substances, chemical reactions, and thermodynamics (Rita & Guspatni, 2024). However, this concept was often considered difficult to visualise, thus hindering learners from comprehensively understanding the subject matter (Yuniarto et al., 2025). Static and less interactive visualisations made it difficult for learners to understand the dynamic processes that occurred during chemical bond formation (Hakim et al., 2024). Unfortunately, conventional studying media such as textbooks and whiteboards have not been able to optimally present the visualisation of this concept, so learners were more likely to memorise than to understand (Puspitarini & Hanif, 2019).

The results of initial observations at MA Al-Washliyah 36 Serbelawan showed that the study process was still centred on teachers, and had not fully utilised digital media. During the observation, it was found that the study process was still teacher-centred. In addition, the instructional media used were still conventional, such as textbooks and whiteboards, which had limitations in presenting the abstract and complex concept of atomic bonding. The teaching and studying process lacked the integration of technology, such as YouTube, Quizizz, PowerPoint, and Augmented Reality, which may have contributed to the learners' average scores ranging from 65 to 75 on atomic bonding material, falling short of meeting the completeness criteria. This indicated the need for more engaging, interactive studying media that supported independent studying.

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The advent of the digital era has brought about significant opportunities for developing technology-based learning media, thanks to advancements in ICT (Julita & Purnasari, 2022). One promising innovation is AR, a technology that seamlessly integrates the real and virtual worlds in real-time through digital devices, offering new possibilities for interactive and immersive studying experiences (Wahiddiyah et al., 2023). In the context of chemistry studies, AR allowed learners to see 3D models of molecules, bond formation processes, and molecular geometric shapes interactively and engagingly (Simbolon & Muchtar, 2025). Previous research has proven that the use of AR could improve concept understanding, studying motivation, and create a more enjoyable and meaningful studying experience (Suteja & Warsito, 2024). However, the use of AR in the form of interactive digital magazines for chemistry studying was still very limited (Damanik et al., 2024). In fact, this media had the potential to present material in a visual, concise, and familiar manner for learners.

AR in the context of chemistry studies can be used to visualise molecular structures, chemical bond formation processes, and molecular geometry in an interactive 3D manner (Hermawan et al., 2025). By using AR, learners can see firsthand how atoms interact and form chemical bonds, as well as how the molecules are oriented in three-dimensional space (Putri et al., 2024).

Previous research has shown that incorporating AR in chemistry education can positively impact learners' comprehension of abstract concepts, boost their motivation to learn, and create a more engaging and interactive studying environment (Utama et al., 2024). Thus, the use of AR in studying atomic structures makes studying more interactive, interesting, and effective for learners (Rio et al., 2023). AR can make abstract concepts more tangible and accessible by visualising them in a way that's easier for learners to understand and interact with (Einsthendi et al., 2024).

The first factor that affects the success of AR implementation is learner involvement in the use of AR, which, by interacting directly with studying content, encourages active participation (Sugiarso et al., 2024). Research has shown that AR can enhance learners' understanding and achievement, boost motivation, and make studying more enjoyable. Studies have found a significant positive impact of AR on studying outcomes (Ananda, 2025). Specifically, interactive Android-based AR applications for chemistry have been effective in improving learner studying outcomes and are suitable for senior high school levels, promoting engaging and independent studying experiences (Kartini, 2024).

This research focused on developing an innovative interactive digital magazine utilising augmented reality (AR) technology to enhance the studying experience of chemical bonds for room X learners. The magazine featured 3D visualisations, animations, quizzes, and educational content designed to boost learner engagement. The goal was to create a valid, practical, and effective studying tool that could significantly contribute to improving the quality of chemistry at the high school.

Methods

The 4D model is a suitable framework for developing and studying products (Maulida et al., 2023). The goal was to create an Augmented Reality (AR)-based interactive digital magazine for chemistry students, specifically on atomic bonding material for room X learners. The study involved 25 learners from room X of MA Al-Washliyah 36 Serbelawan, selected through random sampling. Two rooms were taken, with one serving as the experimental room to improve studying outcomes and the other as a control room.

The development process involved four stages: In the define stage, a needs analysis was conducted, learning objectives were identified, and relevant initial information was gathered to support the development of the media. The Design stage involved the initial design of the digital magazine media based on Augmented Reality (AR), including content structure, layout design, and AR technology integration and choosing the right software, namely the Canva and Assembler Edu applications. The Develop stage covered the development of the initial product, expert validation, revisions, and limited trials to gather necessary feedback. Subsequently, in the Disseminate stage, a large-scale trial was conducted to measure the effectiveness of the developed media. This trial used a quasi-experimental design involving experimental and control classes of tenth-grade students. The aim was to determine the extent to which the AR-based digital magazine could improve students' learning outcomes, particularly on the topic of chemical bonding.

Thus, in addition to focusing on media development, this study also included aspects of product effectiveness testing, product practicality, and student responses to its use. The study utilised various instruments, including expert validation sheets, pre-test and post-test questions to assess studying outcomes, teacher practicality questionnaires, and learner response questionnaires.

Involve a collection of data pretest and posttest to assess the effectiveness of the developed media, with studying outcome analisis using N-Gain steps measure improvement (Ayatillah et al., 2024). The tests were conducted for validity, difficulty level, discriminatory power, and reliability, and only those meeting the criteria were used to determine the media's effectiveness.

In addition, qualitative data were obtained from the practicality questionnaire given to teachers and the response questionnaire from learners regarding the ease of use and attractiveness of the media. All research procedures were carried out in accordance with the principles of research ethics, and the developed media were tested directly in the study process to ensure their suitability with

educational needs in the context of chemistry studies.

Results and Discussion

Define

This stage aims to analyse the needs and problems for media development. The analysis was carried out through observations, interviews with chemistry teachers, and questionnaires to learners of room X of MA Al-Washliyah 36 Serbelawan. It was found that learners were less interested in atomic bonding material because of monotonous delivery, lack of technology, and reliance on packaged books. The average score of learners ranges from 60 to 70. Learners also expressed the need for interactive and technology-based learning media. Based on these conditions, an interactive digital magazine media based on Augmented Reality (AR). Studying media that involves learners to interact directly and allows them to visualise 3D shapes can help learners become more interested in studying chemical materials. This is in line with research by Setiawan (2021), who explained the importance of using media that is able to involve learners and provide a real 3D appearance. According to Fadilla et al. (2025), it was developed to visually display the content of chemical bonds through 3D models, strengthen the connection with daily life, and support the learner-centred and competency-based studying approach of the Independent Curriculum. Hidayat et al. (2022) stated that chemical bonding was a difficult topic for students to understand due to its abstract nature. Therefore, appropriate, engaging, and user-friendly learning media were needed to support students' comprehension. Similarly, Utami et al. (2025) explained that the use of technology-based media, such as smartphones, had the potential to enhance students' interest and participation in learning. The use of Augmented Reality (AR)-based digital magazines served as an effective solution to help students grasp abstract concepts. This media allowed independent visualisation of ion bonds, covalent bonds, and molecular geometry through interactive 3D displays, thereby improving student engagement and conceptual understanding.

Design

This stage includes media design and the selection of study models. The digital magazine media was designed using Canva because it provides interactive templates, attractive visual elements, and easy access at no huge cost. According to research by Mayasri et al. (2024), the Canva application is very effective for more interesting studying media. Rahmawati et al. (2024) highlighted Canva's advantages in saving time and its practicality, as it could be accessed via both laptops and smartphones. Sugeha et al. (2025) added that Canva offered various illustrations, fonts, colours, and animations that supported creative design. Based on previous studies, this research utilised Canva to design a digital magazine by selecting A4 paper size and adding relevant text, content, visuals, and animations. The finished magazine was then integrated with Assemblr to create AR elements that visualised the 3D image design.

AR visualisations are created with Assemblr Edu to display 3D models of chemical bonds and molecular geometry. Learners can access the AR display by scanning the QR code integrated in the magazine. Hikmah et al. (2023) found that Augmented Reality (AR) helped improve students' understanding of abstract material. Through 3D visualisation and QR code scanning, Assemblr Edu facilitated learning of chemical bonds and molecular geometry more concretely and engagingly. The chosen studying model was Discovery Studying, as it supported active, independent, and learner-centred studying according to the Independent Curriculum. This model helps learners understand concepts in depth through interactive technology-based exploration. AR visualisations had been created with Assemblr Edu by the addition of 3D objects and the creation of QR codes, which were then integrated into the magazine design. According to research by Kartini (2024), AR, when integrated into studying, improves outcomes by engaging learners independently in the studying process. Based on previous studies, the researcher used Canva and Assemblr Edu to develop an AR-based digital magazine. It could be seen in **Figure 1**. A magazine design was created using the canva application, and a 3D AR object was created in Assemblr Edu.

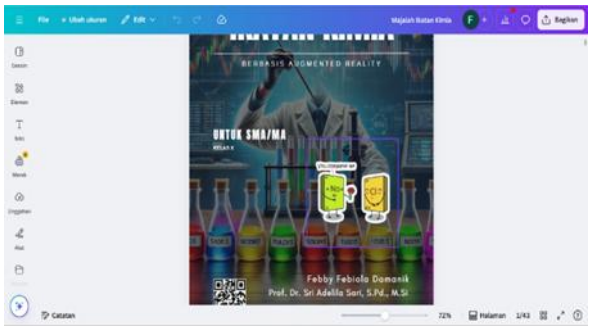


Figure 1. Edited the magazine using the Canva application

Develop

Material experts assessed content feasibility, linguistic aspect, presentation, and graphics, while media experts evaluated media size, display feasibility, content feasibility, and effectiveness. Revisions were made based on their assessments to improve the product.

In the magazine, images related to the sub-subject matter were included. However, the author did not attach the sources of the displayed images, so the validators advised including the source of each image. It could be seen in **Figure 2**—improvements based on the validators' suggestions.



(a) (b)

Figure 2. Image source (a) before revision and (b) after revisions

The magazine included a QR code to connect images in the media with AR to display 3D shapes. Initially, the size of the QR codes varied, so the validators gave suggestions to change and adjust them. After completing the editing in the Canva application, Assemblr Edu was then used to create AR content by adding 3D objects. The QR code for the AR was subsequently generated and linked to the Canva design (Mayasri et al., 2024). The improvements based on the validators' suggestions could be seen in **Figure 3**.



(a) (b)

Figure 3. QR code size (a) before revision and (b) after revision

Two media mater experts and two subject experts validated the AR-based digital magazine using a Likert scale (1-4). The validation stage assessed the product's feasibility, ensuring it met required standards before further implementation Mukholifah et al. (2020) said that the finished product had to go through the validation stage by an expert validator. Fasna et al. (2024) stated that validation was essential to ensure the feasibility of learning media for school use. **Table 1** shows the average score and percentage for each aspect.

Table 1. Validation Result by Subject Matter Experts

Aspect	Average score	Percentage (%)	Category
Content Feasibility	42	95.45	Very Valid
Languange	7.5	93.75	Very Valid
Presentation	11.5	95.83	Very Valid
Graphics	7.5	93.73	Very Valid
Average	-	95.1	Very Valid

Validation result is two subject matter experts showed that the overall average was 95.10%, which was categorised as very valid based on the BSNP standard. Thus, the AR-based digital magazine media was considered to be very suitable for use in studying. In accordance with Mukarromah & Andriana (2022), the material in learning media needed to be presented in detail to stimulate students' motivation and interest in learning. Damayanti et al. (2018) explained that if the material feasibility score assessed by validators fell within the range of 81% to 100%, the electronic pocket book media was considered valid and highly suitable for use. Furthermore, the analysis of the electronic pocket book media was carried out by media experts, as shown in **Table 2**.

Table 2. Validation result by subject media experts

Aspect	Average score	Percentage (%)	Category
Media Size	7.5	93.75	Very valid
Display Feasibility	19.5	97.5	Very valid
Content Feasibility	22	91.66	Very valid
Effectiveness	8	100	Very valid
Average	-	95.5	Very valid

The media experts' validation results showed a 95.00% overall average, suggesting the AR-based digital magazine media was highly feasible and valid for use. According to the BSNP standards, these results were categorised as very valid; therefore, the AR-based digital magazine media was declared suitable for use in studying. Based on this assessment, a score in the range of 81%–100% was obtained. Thus, it was concluded that the electronic pocket book media was valid or highly feasible.

Disseminate

The validated AR-based digital magazine was implemented in an experimental room of 25 grade X learners, while a control room used conventional media. Pretests and posttests were administered to both rooms to measure the media's effectiveness, using questions that had been validated and tested for reliability, difficulty, and discriminatory power. The average results for both rooms are presented based on **Tabel 3**.

Table 3. Averages pretest and posttest

Room	Pretest	Postest
Experiment	38.8	86.8
Control	33.5	72.2

The experimental room showed a significant improvement in studying outcomes, with average pretest and posttest scores of 38.8 and 86.8, respectively. In contrast, the control room had average scores of 33.5 and 72.2. Nurfadilah et al. (2024) reported improved student learning outcomes after using AR media with 3D visualisations in chemistry. Similarly, Vari et al. (2023) found that AR use in science led to significant achievement gains. In line with the study by Sari et al. (2025), the use of technology in the development of learning media had a positive impact on students' learning outcomes by presenting the material in a more contextual and

easily understandable manner. Media involving technology was able to demonstrate student engagement and motivation in learning abstract concepts. These findings showed that AR-based interactive digital magazines were effective in enhancing student understanding of chemical bonding because they were technology-related. The results are presented in **Table 4**, indicating a greater enhancement in learner studying outcomes in the experimental room.

Table 4. N-Gain score

Room	N-Gain	Std, Dev	Lowest	Highest	Category
Experiment	0.7964	0.9031	0.67	1.00	High
Control	0.5820	0.1196	0.27	0.75	Medium

A notable disparity was found between the experiment and control group's Ngain score. With an average N-gain score of 0.7964 (79.64%), classified as high, the experimental group outperformed the control group, which scored 0.5820 (58.20%), falling into the medium category. This suggests the AR-based digital magazine had a substantial positive impact on the study outcomes in the experimental group. The research results showed that the digital magazine media based on Augmented Reality (AR) that was developed proved to be effective in improving students' learning outcomes on the topic of chemical bonding. This was demonstrated by the increase in the students' average scores in the experimental class after using the media, as well as the N-gain values, which fell into the medium to high categories.

The effectiveness of this media could be explained by its interactive and engaging characteristics. AR technology allowed students to directly view three-dimensional visualisations of chemical bonding structures through their smartphones. These visualisations helped students build a stronger conceptual understanding because they did not merely read or see flat images, but were able to observe the shape and bonding processes between atoms in a more tangible and contextual form. In addition, the media was designed in the form of a digital magazine containing material explanations, illustrations, videos, and links to AR features, which encouraged active student engagement in the learning process. The combination of digital content and AR technology also made learning more enjoyable and less monotonous, ultimately increasing students' motivation and understanding.

This study's results are consistent with the prior search by Purwanti et al. (2024) that developed an AR-based chemistry study media using Unity, which achieved a high Ngain score of 0.87, demonstrating significant efective in enhancing study outcomes. However, our search diverges by exploring an AR-based interactive digital magazine, which provides distinct advantages, including user-friendliness and multimedia integration, to boost learner engagement. Based on the research conducted, it was in line with previous studies that media using AR was effective in improving learning outcomes. To validate data suitability for parametric statistical analysis, normality in **Table 5** and the homogeneity test were performed before the hypothesis test.

Table 5. Data on the normality of studying outcomes

Room	Data Source	Shapiro-Wilk (Sig)	Information
Experiment	N-gain	0.187	Normal
Control	N-gain	0.101	Normal

Normal test uses the Shapiro-Wilk method, yielding significant values of 0.187 for the experimental room and 0.101 for the control room, both exceeding the 0.05 threshold. The homogeneity test results are presented in **Table 6**, further assessing the equality of variances between the two rooms.

Table 6. Studying outcome homogeneity test data

Data Source	Levene Statistic	df1	df2	Sig.	Information
N-gain	0.564	1	48	0.456	Homogeneous

The Levene test confirms data homogeneity with a significance value of 0.456 (>0.05). The hypothesis test result revealed a significant difference, with a Sig. (2-tailed) value of 0.000 (<0.05). This indicates that the AR-based interactive digital media magazine had a significant positive impact on Grade X learner study outcomes at MA Al-Washliyah 36 Serbelawan.

Practicality of AR-based digital magazine

The practicality of the media was measured based on the teachers' responses to the use of AR-based digital magazines on atomic bonding material. In this study, two teachers from MA Al-Washliyah 36 Serbelawan were involved as validators to assess the practicality of the media. The results of teachers' practicality assessments of the AR-based digital magazine were presented in **Table 7**.

Table 7. Assessment of teachers' practicality of AR-based digital magazine media

Aspect	Average score	Percentage (%)	Category
Content Feasibility	18.5	92.5	Very Practical
Presentation	14.5	90.6	Very Practical
Design	7.5	93.75	Very Practical
Languange	12	100	Very Practical
Average	-	93.74	Very Practical

Based on **Table 7**, it was found that the practicality validation percentages by Teacher 1 and Teacher 2 were 94.64% and 93.74%, respectively, both of which were categorised as very high. These results indicated that the AR-based digital magazine was highly practical and suitable to be used as a study medium for atomic bonding material, and did not require any revisions. The study supported this finding, conducted by Irma et al. (2024), which showed that AR-based media developed with Unity was practically used in studying. The digital magazine media based on Augmented Reality (AR) was considered practical by teachers because it could be easily operated through digital devices such as smartphones, making it accessible repeatedly. Its attractive design and the media's ability to present material visually and interactively were added values in the learning process. In addition, this media helped teachers deliver material without the need for additional teaching aids, thereby making the teaching preparation process more efficient. These findings were in line with the study by Muchtar et al. (2021), which stated that the use of technology in instructional media could enhance efficiency and practicality, as technology was able to present material engagingly, as well as encourage active student participation in the learning process.

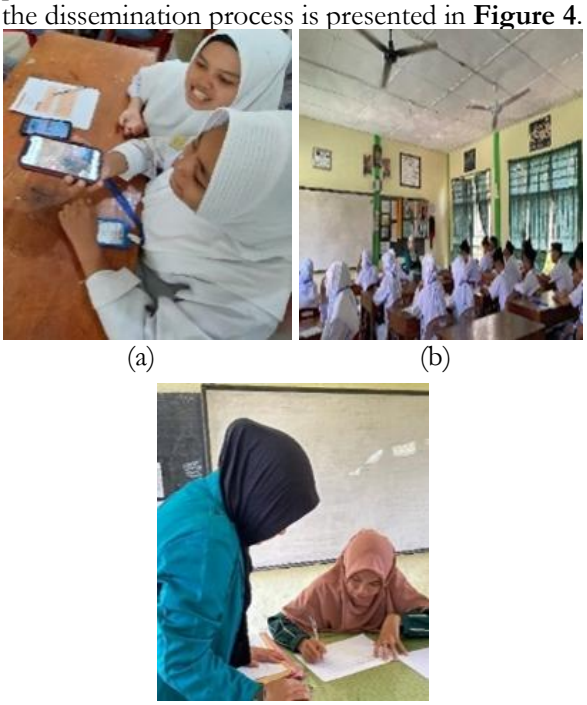
Learner response to the media

After the learners used the AR-based interactive digital magazine media during the study activities, a questionnaire was distributed to measure their responses to the media usage. The questionnaire consisted of 20 items, with a point scale ranging from 1 to 4. The results of the learners' responses to the use of the AR-based digital magazine media were presented in **Table 8**.

Table 8. Data on the results of learner responses to AR-based digital magazines

Data	Total Score	Average (%)	Category
Learner Response	2.284	91.36	High

The percentage of learners in this Ar-based interactive digital magazine media was 91.36%, categorised as high, indicating strong agreement that the media improved studying outcomes. This finding aligns with Vari et al. (2023) study, which reported positive learner responses to AR media due to its ability to engage learners actively. Students' responses to the developed learning media showed highly positive reactions. This was due to the media's ability to present contextual material by connecting the content to students' real-life experiences. This finding was in line with the study by Sari & Marbun (2025), which stated that media capable of linking learning to real-life situations and presenting it in a way that can be directly observed by students helped them better understand abstract concepts. The high learner response rate in both studies suggests that AR-based media can enhance learner engagement and studying experiences, and the effectiveness of the media. The direct interaction of learners created a more engaging and dynamic studying atmosphere, making the studying process less monotonous. The documentation of the dissemination process is presented in **Figure 4**.



(a) (b) (c)

Figure 4. Documentation during the dissemination phase was conducted

Conclusions

The development of AR-based interactive digital magazine media for atomic bonding material has yielded impressive results, showcasing its validity, effectiveness, practicality, and appeal to learners. With high validation rates from experts and significant improvements in studying outcomes, this media offers a promising innovation for enhancing chemistry education.

The findings confirm that the AR-based interactive digital magazine effectively enhances conceptual understanding through immersive and interactive 3D visualisations, aligning with the research's primary objective of creating engaging studying media. Further research suggests adding audio features, interactive animations, and involving a broader sample to see the long-term impact of using AR media.

Conflict of Interest

The author stated that the research on the development of Augmented Reality-Based Interactive Digital Magazine Media for class X chemical bond learning was carried out without any commercial or financial relationship that could be interpreted as a potential conflict of interest. The research was not funded by software development companies, publishers, or other parties that had a direct interest in the products developed.

The entire process of designing, developing, implementing, and evaluating the media was carried out independently by the researchers with the aim

of developing learning innovations under the guidance of supervisors. Thus, there were no commercial, financial, or personal interests that could have affected the results or conclusions of the study

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References

Ananda, P. P. (2025). Peran augmented reality sebagai media pembelajaran interaktif di jenjang pendidikan SMP: Suatu kajian literatur sistematis. *Ganesha Civic Education Journal, 7*(2), 147–155. https://doi.org/10.23887/gancej.v7i2.6238

Ayatillah, A. M., Budiyanto, M., & Qosyim, A. (2024). Efektivitas penggunaan media kartu kuartet untuk meningkatkan hasil belajar siswa. *BIOCHEPHY: Journal of Science Educational, 4*(2), 738–744. https://doi.org/10.52562/biochephy.v4i2.1263

Damanik, S. A., Silaban, R., & Nurfajriani. (2024). Pengembangan media mobile Augmented Reality (AR) untuk siswa kelas XII SMA pada materi senyawa turunan alkana. *Didaktika: Jurnal Kependidikan, 13*(2), 2203–2216. https://doi.org/10.58230/27454312.735

Damayanti, A. E., Syafei, I., Komikesari, H., & Rahayu, R. (2018). Kelayakan media pembelajaran fisika berupa buku saku berbasis android pada materi fluida statis. *Indonesian Journal of Science and Mathematics Education, 1*(1), 63–70. https://doi.org/10.24042/ijsme.v1i1.2476

Einsthendi, A. D., Rasyid, M. I. A., & Wicaksono, J. B. (2024). Augmented reality: impact on student engagement and learning. *Hipkin Journal of Educational Research, 1*(2), 239–250. https://doi.org/10.64014/hipkin-jer.v1i2.22

Fadilla, A. N., Herdini., & Holiwarni, B. (2025). Development of student worksheets based on the Nature of Science (NoS) on chemical bonds topic. *Unnes Science Education Journal, 14*(1), 16–27. https://doi.org/10.15294/usej.v14i1.19221

Fasna, G. F., Romadhon, D. R., & Nurlaela, A. (2024). Peran penting teknologi dalam pendidikan sains: pengembangan dan validasi media pembelajaran berbasis android dengan app inventor untuk pemahaman materi gelombang cahaya. *Jurnal Pendidikan MIPA, 14*(1), 57–66. https://doi.org/10.37630/jpm.v14i1.1485

Hakim, E., Astafani, A., & Resmawati, R. F. (2024). Systematic review faktor-faktor kesulitan belajar materi kimia. *Jurnal Inovasi Pendidikan Kimia, 18*(2), 81–88. https://doi.org/10.15294/qm1ym619

Hermawan, B., Faqih, A., Dwilestari, G. (2025). Implementasi aplikasi pembelajaran petualangan berbasis Augmented Reality (AR) untuk meningkatkan interaktivitas di SMAN 1 Dukupuntang. *Jurnal Informatika Dan Teknik Elektro Terapan, 13*(1), 609–618. https://doi.org/10.23960/jitet.v13i1.5688

Hidayat, A., Enawaty, E., & Hadi, L. (2022). Peningkatan pemahaman konsep peserta didik melalui media kit covalent creator berbasis multirepresentasi. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa, 11*(7), 616–622. https://doi.org/10.26418/jppk.v11i7.56193

Hikmah, S., Kanzunnudin, M., & Khamdun. (2023). Pengembangan media 3D materi indera pendengaran manusia dengan augmented reality assembler edu. *Journal on Education, 5*(3), 7430–7439. https://doi.org/10.31004/joe.v5i3.1533

Irma, W., Okra, R., Musril, H. A., & Derta, S. (2024). Perancangan media pembelajaran augmented reality (AR) pada mata pelajaran kimia menggunakan unity di SMA Negeri 1 Bukittinggi. *Jurnal Manajemen Informatika (JAMIKA), 14*(1), 54–67. https://doi.org/10.34010/jamika.v14i1.12076

Julita., & Punasari, P. D. (2022). Pemanfaatan teknologi sebagai media pembelajaran dalam pendidikan era digital. *Journal of Educational Learning and Innovation, 2*(2), 227–239. https://doi.org/10.46229/elia.v2i2.460

Junaidi., Firmansyah, F., Hadhiyanto, R., & Husain, A. (2024). Majalah digital sebagai sarana informasi dan promosi pada SMK Plus Multimedia As-Saadah 2. *MAVIB Journal, 5*(2), 188–200. https://doi.org/10.33050/mavib.v5i2.3109

Kartini, K. S. (2024). Pengembangan augmented reality pada aplikasi pembelajaran interaktif berbasis android untuk materi molekul kimia. *Digital Transformation Technology, 4*(1), 341–347. https://doi.org/10.47709/digitech.v4i1.4089

Maulida, L., Murtinugraha, R. E., & Arthur, R. (2023). Model four-D sebagai implementasi untuk pengembangan bahan ajar elektronik modul mata kuliah K3. *Jurnal Pendidikan West Science, 1*(7), 433–440. https://doi.org/10.58812/jpdws.v1i07.532

Mayasri, A., Reza, M., & Rafdi, M. (2024). Membangun era baru pembelajaran: pelatihan pembuatan e-modul praktikum IPA dengan canva. *Jurnal Masyarakat Mandiri, 8*(2), 1927–1936. https://doi.org/10.31764/jmm.v8i2.21763

Muchtar, Z., Sari, S. A., Rahmah, S., Zubir, M., Selly, R., & Damanik, M. (2021). The implementation for natural science online lecture with chemistry

education base at Nurul Fadhillah school Bandar Setia. *Jurnal Pendidikan Kimia, 13*(1), 85–93. https://doi.org/10.24114/jpkim.v13i1.24212

Mukarromah, A., & Andriana, M. (2022). Peranan guru dalam mengembangkan media pembelajaran. *Journal of Science and Education Research, 1*(1), 43–50. https://doi.org/10.62759/jser.v1i1.7

Mukholifah, M., Tisngati, U., & Ardyantama, V. (2020). Mengembangkan media pembelajaran wayang karakter pada pembelajaran tematik. *Jurnal Inovasi Penelitian, 1*(3), 1–4. https://doi.org/10.47492/jip.v1i4.152

Nurfadilah, A., Muis, A., & Rahma, S. (2024). Peningkatan hasil belajar biologi konsep enzim melalui penerapan model pembelajaran discovery pada peserta didik kelas XI Biologi 3 SMA Negeri 2 Makassar. *Jurnal Pemikiran Dan Pengembangan Pembelajaran, 6*(2), 226–230. https://doi.org/10.31970/pendidikan.v6i2.485

Purwanti., Diana, R., Mulaydin., Yusup, F., & Fauzi, R. N. (2024). Penggunaan media augmented reality dalam pembelajaran IPA untuk meningkatkan pemahaman konsep. *Jurnal Informatika dan Teknologi Pendidikan, 4*(2), 67–73. https://doi.org/10.59395/jitp.v4i2.98

Puspitarini, Y. D., & Hanif, M. (2019). Using learning media to increase learning motivation in elementary school. *Anatolian Journal of Education, 4*(2), 53–60. https://doi.org/10.29333/aje.2019.426a

Putri, N. S., Wasih, D. A., & Sabekti, A. W. (2024). Challenges for learning chemical bonding materials based on the concept of electrostatic interaction and the octet rule. *SPIN: Jurnal Kimia dan Pendidikan Kimia, 6*(1), 34–41. https://doi.org/10.20414/spin.v6i1.9303

Rahayu, P., Saridewi, N., & Herpi, A. N. (2024). Pengaruh metode pembelajaran bermain peran terhadap kemampuan berpikir kreatif siswa pada materi koloid. *Jurnal Pendidikan, 25*(1), 20–29. https://doi.org/10.33830/jp.v25i1.7433.2024

Rahmawati, L., Suharni., Ambulani, N., Febrian, W. D., Widyatiningtyas, R., & Rita, R. S. (2024). Pemanfaatan aplikasi canva dalam penyusunan media pembelajaran berbasis teknologi. *Communnity Development Journal: Jurnal Pengabdian Masyarakat, 5*(1), 129–136. https://doi.org/10.31004/cdj.v5i1.24151

Rio, B., Assidiq, M., & Syarli. (2023). Aplikasi pembelajaran sains kimia pada SMK Bigem (Bina Genari Mandiri) berbasis augmented reality (AR). *Journal Peqguruang: Conference Series, 5*(2), 861–869. http://dx.doi.org/10.35329/jp.v5i2.4419

Rita, O. O., & Guspatni, G. (2024). Teknologi augmented reality (AR) dalam pembelajaran kimia, tinjauan pustaka: bentuk-bentuk, hambatan dan pemanfaatan augmented reality (AR) dalam pembelajaran kimia. *Jurnal Pendidikan Tambusai, 8*(2), 18552–18562. https://doi.org/10.31004/jptam.v8i2.15094

Sari, S. A., & Marbun, C. J. H. (2025). Development of contextual-based chemistry teaching materials on the subject of buffer solution in senior high school. *EDUPROXIMA: Jurnal Ilmiah Pendidikan IPA, 7*(1), 60–73. https://doi.org/10.29100/.v7i1.6200

Sari, S. A., & Tioro, M., & Lubis, E. (2021). Development of android chemistry comics as an independent learning application to improve student learning outcomes. *Jurnal Pendidikan Sains Indonesia, 9*(3), 433–444. https://doi.org/10.24815/jpsi.v9i3.20266

Sari, S. A., Dewi, R. S., Saputra, K., Kembaren, A., Hasibuan, H., & Talib, C. A. (2025). Integration of analytical chemistry flipbooks based on project-based learning in improving critical thinking skills and scientific literacy to support sdg-4. *Jurnal Pendidikan IPA Indonesia, 14*(1), 59–69. https://doi.org/10.15294/jpii.v14i1.21038

Setiawan, A. H. (2021). Studi terhadap media augmanted reality (AR) dalam meningkatkan hasil belajar peserta didik pada KD memahami jenis-jenis alat berat. *Jurnal Kajian Pendidikan Teknik Bangunan (JKPTB), 7*(1), 1–5. https://doi.org/10.26740/jkptb.v7i1.37593

Simanjuntak, C. Y. B., & Purba, J. (2024). Pengembangan e-modul berbasis discovery learning dengan bantuan flip pdf corporate edition pada materi ikatan kimia. *Jurnal Pendidikan Kimia FKIP Universitas Halu Oleo, 9*(1), 26–39. https://doi.org/10.36709/jpkim.v9i1.79

Simbolon, E., & Muchtar, Z. (2025). Development of android-based augmanted reality learning media on chemical bonding material in class XI SMA N 1 Sidikalang. *Eduproxima: Jurnal Ilmiah Pendidikan IPA, 7*(1), 43–49. https://doi.org/10.29100/.v7i1

Sugeha, S., Tombokan, A. C., Walewangko, E. A., Wiwin, K., Kaunang, D. F., Regar, V. E., & Pulukadang, R. J. (2025). Peningkatan kompetensi visual siswa melalui desain digital canva di SMK Negeri 2 Tondano. *Jurnal Pengabdian Masyarakat Dan Riset Pendidikan, 3*(4), 3479–3488. https://doi.org/10.31004/jerkin.v3i4.1067

Sugiarso, B. A., Narasiang, B. S., Pranajaya, S. A., Gunawan, T., Fayola, A. D., Marzuki, & Arifianto, T. (2024). Penerapan teknologi augmented reality dalam menyajikan materi pembelajaran untuk meningkatkan minat belajar siswa. *Jurnal Review Pendidikan Dan Pengajaran, 7*(2), 4999–5004. https://doi.org/10.31004/jrpp.v7i2.27550

Suteja, M., & Warsito, A. B. (2024). Media pembelajaran kimia berbasis AR. *Modem: Jurnal Informatika Dan Sains Teknologi, 2*(2), 29–41. https://doi.org/10.62951/modem.v2i3.157

Utama, I. K. W., Rahayu, K. M., Azizah, L. F., Winarti., Sitopu, J. W., & Wiliyanti, V. (2024). Pengaruh penggunaan teknologi augmented

reality dalam pembelajaran IPA terhadap pemahaman materi pembelajaran. *Jurnal Review Pendidikan Dan Pengajaran, 7*(3), 7813–7821. https://doi.org/10.31004/jrpp.v7i3.29869

Utami, M. S., Afrida., & Asmiyunda. (2025). Pengembangan media pembelajaran powerpoint interaktif materi ikatan kimia berbasis scientific approach untuk menumbuhkan literasi kimia peserta didik. *Jurnal Pengabdian Masyarakat dan Riset Pendidikan, 3*(4), 1995–2005. https://doi.org/10.31004/jerkin.v3i4.691

Vari, Y., Sarwanto., & Yamtinah, S. (2023). Development of inquiry-based solar system augmented reality science learning media. *Jurnal Penelitian Pendidikan IPA, 9*(12), 11165–11172. https://doi.org/10.29303/jppipa.v9i12.4529

Wahiddiyah, N. P., Luthfia, A. N., Safitri, D., & Sujarwo. (2023). Pemanfaatan augmented reality dalam pembelajaran IPS menyajikan informasi sejarah dengan realitas tambahan. *Sinar Dunia: Jurnal Riset Sosial Humaniora dan Ilmu Pendidikan, 2*(4), 115–124. https://doi.org/10.58192/sidu.v2i4.1535

Yuniarto, E., Widayantim F. D., Rahayuningsih, S., Rahmani, A. Z., & Setya, C. D. Analisis keterbatasan media pembelajaran: tantangan dan solusi dalam pembelajaran kontekstual. *LEARNING: Jurnal Inovasi Penelitian Pendidikan dan Pembelajaran*, *5*(4), 1643–1654. https://doi.org/10.51878/learning.v5i4.7508