Journal of Educational Chemistry (6(2), 2024, 103-110)
Website:
https://journal.walisongo.ac.id/index.php/jec/index
ISSN 2715-3029 (p) 2685-4880 (e)
DOI: 10.21580/jec.2024.6.2.22801

Development of Chemistry Flashcard (Chemilard) Based on Augmented Reality in Unity 3D for Chemical Bonding Material

Riky Setiawan[1*], Lenni Khotimah Harahap[2]
[1)] Departement of Educational Technology, Universitas Sebelas Maret, Indonesia
[2)] Departement of Chemistry Education, Universitas Islam Negeri Walisongo Semarang, Indonesia

*E-mail Corresponding Author: rikystp24@student.uns.ac.id

Abstract

The lack of variety in instructional media can be a starting point for the difficulty in creating an effective and enjoyable learning environment, particularly in chemistry subjects. The concepts in chemical bonding are abstract, making them difficult to apply contextually. Based on these issues, the researchers developed CHEMILARD (Chemistry Flashcard) media using augmented reality. This research employed the D&D (Design and Development) model. The subjects of this study were 6 expert validators in media and content, as well as 25 respondents. The data analysis techniques included Aiken's analysis and percentage models. The study concluded that the validation of CHEMILARD media, developed across all assessment aspects, indicated that the product is feasible for trial implementation with a score of V=0.90 from media experts and V=0.91 from content experts. The respondents' test results showed an ideal media percentage of 90.3% and an overall media quality rating of 76.72, which is categorized as Very Good. This indicates that the augmented reality-based CHEMILARD media can significantly enhance the learning experience by making abstract chemical bonding concepts more tangible and easier to understand for students.

Keywords: augmented reality; chemical bonding; flashcards; learning media

Abstrak

Kurangnya variasi media pembelajaran dapat menjadi titik awal sulitnya menciptakan lingkungan belajar yang efektif dan menyenangkan, khususnya pada mata pelajaran kimia. Konsep ikatan kimia bersifat abstrak sehingga sulit diterapkan secara kontekstual. Berdasarkan permasalahan tersebut peneliti mengembangkan media CHEMILARD (Chemistry Flashcard) dengan menggunakan augmented reality. Penelitian ini menggunakan model D&D (Design and Development). Subjek penelitian ini adalah validator ahli media dan konten sebanyak 6 orang, serta 25 responden. Teknik analisis datanya meliputi analisis Aiken dan model persentase. Hasil penelitian menyimpulkan bahwa validasi media CHEMILARD yang dikembangkan pada seluruh aspek penilaian menunjukkan bahwa produk layak untuk diterapkan uji coba dengan skor V=0,90 dari ahli media dan V=0,91 dari ahli konten. Hasil uji responden menunjukkan persentase media ideal sebesar 90,3% dan penilaian kualitas media secara keseluruhan sebesar 76,72 yang dikategorikan Sangat Baik. Hal ini menunjukkan bahwa media CHEMILARD berbasis augmented reality dapat meningkatkan pengalaman belajar secara signifikan dengan membuat konsep abstrak ikatan kimia menjadi lebih nyata dan mudah dipahami siswa.

Keywords: augmented reality; flashcards; ikatan kimia; media pembelajaran

Introduction

In the era of the Industrial Revolution 4.0 and Society 5.0, cross-sector participation has become imperative to keep pace with rapid technological advancements (Sukmana & Rozi, 2017). The utilization of technology in various aspects, including decision-making, document processing, and learning, is now crucial (Rusman, 2013). Technological development in Indonesia supports learning activities through various new media, with technology playing a vital role in creating a bright future (Nurillah & Purwanto, 2023). In the context of learning, technology not only empowers students to acquire and process information but also assists teachers in enhancing their teaching skills (Nurdyansyah, 2019).

Observations at SMAN 3 Semarang show that students actively use the internet and smartphones in learning. However, the variety of learning media used remains limited, with a dominant preference for PowerPoint presentations and textbooks. This limitation may hinder the creation of more effective and engaging learning, especially in subjects considered difficult, such as chemistry.

Chemistry focuses on understanding the composition, structure, and properties of matter, from the atomic to the molecular level, including the interactions between molecules that form various materials (Dwinata et al., 2016). Learning chemistry particularly on the topic of chemical bonding, involves abstract concepts that are difficult to apply in practical contexts, posing challenges for students (Ozdemir & Sahin, 2018). The difficulty in understanding chemical bonding concepts is evident from observations at SMAN 3 Semarang, where 65.5% of eleventh-grade science students reported difficulties with the material. Previous research also shows that the understanding of chemical bonding concepts is low among students (Fauziyah, 2016). Observations at MA Lamongan noted that 80% of students had difficulty understanding chemical bonding, while boredom with the learning process arose due to a lack of student engagement with the material being taught (Nurillah & Purwanto, 2023). The difficulty in grasping the abstract nature of chemical bonding highlights the need for technology, such as Augmented Reality, which can produce three-dimensional visualizations and molecular structures to enhance students' understanding (Chang et al., 2013; Santos et al., 2014). Based on the problems outlined, a more varied and interactive learning approach is needed, supported by technology to facilitate the understanding of abstract material and increase student engagement in the learning process (Bacca et al., 2014; Ibáñez & Delgado-Kloos, 2018).

Augmented Reality (AR) is a technology that integrates virtual reality with the real world through electronic devices, allowing visual objects to be displayed in three dimensions as if they exist in the real environment (Pramono & Wiratama, 2018). The advantages of AR offer an effective solution to overcoming students' difficulties in understanding the abstract concepts of chemical bonding. Observations of student needs show strong support for the use of AR technology in chemistry learning, with approximately 94.8% of students showing positive interest. Chemistry teachers at SMAN 3 Semarang also positively support the use of AR technology to facilitate students' visualization of chemical bonds or molecular structures (Hastani, interview, March 14, 2023). To make the use of AR more interactive and efficient, this study developed learning media in the form of Augmented Reality-based flashcards that can be used by students in various locations (Wu et al., 2013; Hwang et al., 2015).

Learning media in the form of flashcards with physical dimensions of 6 x 10 cm are expected to be easy-to-use tools for students during the learning process. Flashcards are anticipated not only to facilitate learning but also to enhance its effectiveness by encouraging active student engagement, both through peer interaction and with teacher assistance (Mat et al., 2016).

Observations with eleventh-grade science students at SMAN 3 Semarang indicate that 91.4% of students have never

used flashcards in chemistry learning. Interviews with chemistry teachers also reveal a lack of flashcard use in chemistry teaching activities.

Therefore, researchers have developed CHEMILARD (Chemistry Flashcard) based on Augmented Reality as a solution to overcome students' difficulties in understanding abstract concepts in chemical bonding material.

Method

The development of CHEMILARD based on Augmented Reality follows the steps of the Design and Development (D&D) Model. According to Peffers et al., the stages in the D&D model are as follows: 1) Identifying the problem; 2) Describing the objectives; 3) Designing and developing the product; 4) Testing the product; 5) Evaluating the test results; and 6) Communicating the test results (Martin & Betrus, 2021). These are the series of steps taken by researchers in the process of developing the CHEMILARD learning media.

Result and Discussion

The validation process involved six experts in media and subject matter, consisting of four chemistry education lecturers with expertise in their fields and two chemistry educators who are also experts in their fields. The results of the validation of the CHEMILARD learning media based on AR have been obtained. Media experts' validation includes two aspects of assessment: the extent to which CHEMILARD media captures users' attention and the evaluation of its appearance. On the other hand, subject matter experts' validation focuses on the material aspects contained in CHEMILARD. The detailed results of the validation of the CHEMILARD learning media by media and subject matter experts can be found in Table 1 and Table 2.

Table 1
Media Expert Validation Results for CHEMILARD

No	Assessment Aspect	Validation Score	Criteria
1	3D display on the Android application	0.92	Valid
2	Use of Augmented Reality technology on CHEMILARD cards	0.92	Valid
3	Use of the CHEMILARD Android application	0.88	Valid
4	Design appearance on CHEMILARD cards	0.92	Valid
5	Background music, sound, and sound effects on the application	0.92	Valid
6	3D objects and animations displayed on the application	0.96	Valid
7	Font type, size, color, and paper quality on CHEMILARD cards	0.83	Valid
8	Features in the CHEMILARD media	0.88	Valid
Average		0.90	Valid

The CHEMILARD learning media based on AR has been declared suitable for testing with students by media and subject matter experts. The final appearance of the learning media can be seen in the following Figure.

The menu scene as depicted in Figure 1 will serve as the main menu for the CHEMILARD application. This menu will feature six function buttons: Play, Profile, About, Help, Application Simulation Video, and Exit. The Play button will facilitate a transition to the Play scene and activate the smartphone's camera for augmented reality (AR) scanning.

Table 2
Subject Matter Expert Validation Results for CHEMILARD

No	Assessment Aspect	Validation Score	Criteria
1	Alur Tujuan Pembelajaran (ATP)	0,96	Valid
2	Content based on the Merdeka Curriculum	0,96	Valid
3	Material comprehension in CHEMILARD	0,92	Valid
4	Content based on textbooks for high school level	0,83	Valid
5	Language used in CHEMILARD	0,92	Valid
6	Sentences and word usage in CHEMILARD	0,88	Valid
Average		0,91	Valid

Figure 1
CHEMILARD Menu Scene

The Play scene, as depicted in Figure 2, is where the smartphone's camera scanner is activated. This scene also includes seven function buttons: three for chemical bonding materials (ionic bonding, covalent bonding, and metallic bonding), one menu button, and three for sound playback (play, pause, and stop).

The augmented reality technology in CHEMILARD functions such that each card displays a 3D atomic object corresponding to the element depicted on the card. When two element cards are brought close together, an animation of the 3D object representing the chemical bonding process will be displayed.

Figure 2
CHEMILARD Play Scene

Figure 3 illustrates the marker card used in the CHEMILARD media, consisting of a total of 24 element cards. Each marker card is capable of displaying a 3D object representing the element depicted on the card and can visualize the chemical bonding process when two cards are brought into proximity. Learners can comprehend ionic, covalent, and metallic bonding reactions at the submicroscopic level with the aid of the developed scanner application.

Figure 3
CHEMILARD Marker Card

Figure 4 presents an additional content labeled "Did You Know?" provided by the developer. This "Did You Know?" content is located on the back of the marker card, linking the element's use to the Sustainable Development Goals (SDGs).

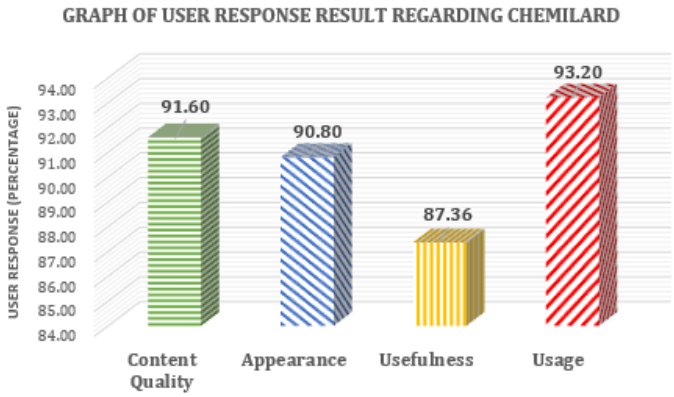
Figure 4
"Did You Know?" Content

The developed CHEMILARD media underwent a feasibility test conducted by media experts and subject matter experts. The results of the expert validation of CHEMILARD have been obtained. Based on the feedback from the media and subject matter experts, several aspects of the CHEMILARD media require revision or addition, including: 1) The design of the front of the marker card should be revised to prevent the scanning of unintended elements; 2) The design of the back of the marker card should be revised to provide a unique design as a distinctive feature of the developed media; 3) An additional example of an ionic compound should be included; and 4) Typographical errors in the chemical bonding material should be corrected.

Following revision and validation by media experts and material experts, subsequent educational media or products

will be tested with users. Respondents then evaluate the product based on four aspects: content quality, usability, appearance, and usefulness. Detailed user response percentages for the CHEMILARD media can be found in Figure 5.

Figure 5
User Response Graph



CHEMILARD is a revolutionary augmented reality-based learning media created using Unity 3D, focusing on the topic of Chemical Bonds. Within CHEMILARD, there are 24 examples of elements and 10 examples of compounds with 3D animation representations that visualize chemical bonding concepts. This represents one of the forefront innovations in educational media, adopting cutting-edge technologies such as augmented reality. Augmented reality proves to be a suitable technology for implementing abstract chemistry learning as it can display 3D visuals of an object through electronic devices as if the object exists in the real world and directly in front of us (Pramono dan Wiratama, 2018).

CHEMILARD, which has been developed, provides students with submicroscopic visualization of chemical bonding reaction processes when the scanner application scans the CHEMILARD marker card. This media assists students in visualizing processes such as ion bonding, covalent bonding, or metallic bonding at the submicroscopic level. Examples of element usage in daily life are also mentioned within the CHEMILARD media on the back of the card and within the application. Researchers have expanded the content on the back of the card into "Did You Know?" segments linking element usage to Sustainable Development Goals (SDGs). The design of the CHEMILARD cards on the front has been carefully arranged, incorporating element symbols, atomic mass numbers, atomic numbers, and electron configurations of chemical elements. The goal is to broaden students' knowledge and understanding of chemistry comprehensively.

The developed CHEMILARD media underwent feasibility testing through evaluations by media and subject matter experts. Validation results by experts regarding CHEMILARD can be found in Tables 1.1 and 1.2. Validation analysis results from media and subject matter experts indicate positive validation scores across all assessed aspects of the developed CHEMILARD media product, meeting the criteria for validity with a score of V=0.90 by media experts and V=0.91 by subject matter experts, based on Aiken's table with 6 raters and using a 5-point scale category. Thus, CHEMILARD media is deemed suitable for testing.

Following its deemed suitability, the next step involved testing with 25 respondents. Results from respondent testing were then analyzed, showing that in terms of content quality, the media achieved 91.6%, categorized as excellent.

For visual appeal, the media scored 90.8%, also falling under the excellent category. Utility received a rating of 87.36%, which also met the criteria for excellence. Meanwhile, in terms of usability, the media achieved 93.2%, again with an excellent rating. Overall, respondent evaluations of the augmented reality-based CHEMILARD media scored 90.3%, which is classified as excellent, with an average score of approximately 76.72.

The researchers acknowledge certain limitations in the development of the AR-based CHEMILARD learning media using Unity 3D for the topic of chemical bonding. These limitations include the media's sole focus on ionic, covalent, and metallic bonding, as well as the novice status of the researchers in media development, resulting in the development process being carried out without the assistance of any professionals.

Conclusion

From the findings and discussion of the study on CHEMILARD, an Augmented Reality (AR)-based media using Unity 3D for Chemical Bonds material, the following conclusions can be drawn CHEMILARD, an Augmented Reality-based learning media using Unity 3D for Chemical Bonds material, consists of 24 element cards displaying 3D objects and chemical bonding processes. The card design aims to facilitate understanding of ion, covalent, and metallic bonding at the submicroscopic level. Additionally, CHEMILARD integrates the usage of elements with Sustainable Development Goals (SDGs). Validation of the developed CHEMILARD media across all assessment aspects indicates the product's suitability for testing, with a score of V=0.90 from media experts and V=0.91 from subject matter experts. Respondent testing yielded an ideal media percentage of 90.3% and an overall quality rating of 76.72 (Excellent). The AR-based CHEMILARD media, developed using Unity 3D for the topic of chemical bonding, still exhibits numerous limitations. This presents opportunities for subsequent researchers to further optimize the product developed by the current researchers, and large-scale trials of the learning media are necessary to determine its effectiveness.

References

Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2014). Augmented Reality Trends in Education: A Systematic Review of Research and Applications. *Educational Technology & Society, 17*(4), 133-149. https://doi.org/10.1111/j.1467-8535.2012.01333.x

Chang, K.-E., Wu, L.-J., & Hsu, C.-T. (2013). Integrating Augmented Reality Technology into Science Education. *Educational Technology & Society, 16*(3), 69-77.

Dwinata, R. A., Efendi, R., & Yudha, S. P. (2016). Rancang Bangun Aplikasi Tabel Periodik Unsur Dan Perumusan Senyawa Kimia dari Unsur Kimia Dasar Berbasis Android. *Jurnal Rekursif*, *4*(2), 176–183.

Fauziyah, N. (2016). *Identifikasi letak kesulitan dan faktor-faktor yang mempengaruhi kesulitan belajkar siswa kelas X IPA SMA Negeri 4 Malang pada materi ikatan kimia* [Universitas Negeri Malang].

Hwang, G.-J., Wu, P.-H., & Chen, C.-C. (2015). An Online Game Approach for Improving Students' Learning Performance in Web-Based Problem-Solving Activities. *Computers & Education, 59*(1), 1246-1256. https://doi.org/10.1016/j.compedu.2012.05.019

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented Reality for STEM Learning: A Systematic Review. *Computers & Education, 123*, 109-123. https://doi.org/10.1016/j.compedu.2018.05.002

Martin, F., & Betrus, A. K. (2021). *Digital Media for Learning: Theories, Processes, and Solutions* (1 ed.). Springer Cham. https://doi.org/https://doi.org/10.100

7/978-3-030-33120-7

Mat, M. Z. A., Sawari, S. S. M., Nawi, N. M., Junit, F., & Othman, M. M. (2016). An Action Research on the Effectiveness Uses of Flash Card in Promoting Hijaiyah Literacy among Primary School Pupils. *Mediterranean Journal of Social Sciences*, *7*(2), 433–438. https://doi.org/10.5901/mjss.2016.v7n2s1p433

Nurdyansyah. (2019). *Media Pembelajaran Inovatif* (P. Rais (ed.)). UMSIDA Press.

Nurillah, H. S., & Purwanto, K. K. (2023). Penggunaan Media Augmented Reality Berbasis Android Terhadap Peningkatakan Prestasi Belajar Siswa Pada Materi Ikatan Kimia. *UNESA Journal of Chemical Education*, *12*(1), 17–22.

Ozdemir, S., & Sahin, S. (2018). The Effect of Augmented Reality Applications in the Learning Process: A Meta-Analysis Study. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(4), 125-131. https://doi.org/10.29333/ejmste/85807

Pramono, A., & Wiratama, F. D. M. (2018). Aplikasi Pengenalan Rumah Adat Indonesia Dengan Konsep 3D-Augmented Reality Berbasis Android. *Konvergensi*, *14*(1), 1–10. https://doi.org/10.30996/konv.v14i1.2766

Rusman. (2013). *Belajar dan Pembelajaran Berbasis Komputer*. Alfabeta.

Santos, M. E. C., Chen, A., Taketomi, T., Yamamoto, G., Miyazaki, J., & Kato, H. (2014). Augmented Reality Learning Experiences: Survey of Prototype Design and Evaluation. *IEEE Transactions on Learning Technologies, 7*(1), 38-56. https://doi.org/10.1109/TLT.2013.37

Sukmana, F., & Rozi, F. (2017). Decision support system on computer maintenance management system using Association Rule and Fisher Exact test One Side P-Value. *Telkomnika (Telecommunication Computing Electronics and Control)*, *15*(4), 1841–1851. https://doi.org/10.12928/TELKOMNIKA.v15i4.5880

Wu, H.-K., Lee, S. W.-Y., Chang, H.-Y., & Liang, J.-C. (2013). Current Status, Opportunities and Challenges of Augmented Reality in Education. *Computers & Education, 62*, 41-49. https://doi.org/10.1016/j.compedu.2012.10.024