Orbital
The electronic journal of chemistry

the electronic journal of chemistry

Paper on Education | http://dx.doi.org/10.17807/orbital.v15i2.17617

Development and Implementation of Augmented Reality-Based Card Game Learning Media with Environmental Literacy for Improving Students' Understanding of Carbon Compounds

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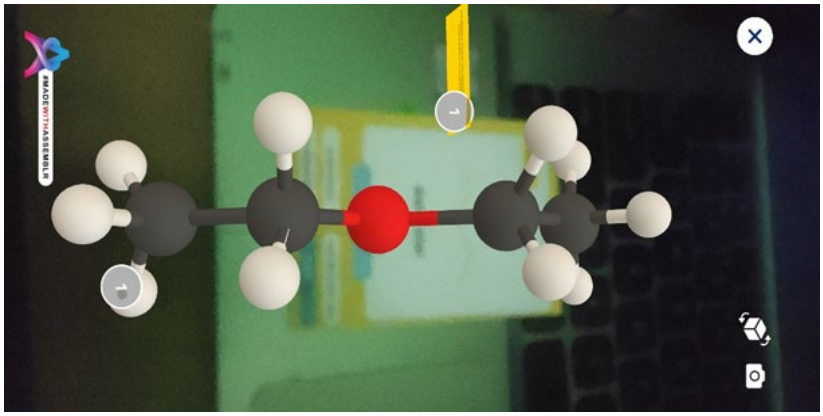
The lack of knowledge integration about the learning environment is one of the causes of the low environmental awareness. The purpose of this study was to develop learning media for carbon compounds based on augmented reality and environmental literacy and to find out student learning outcomes after using media, students' perceptions of the media, and their environmental insight. This research is a research and development (R&D) research by following the ADDIE model. One group pre-test post-test research design was used to examine the effect of using the media. The research instruments were multiple choice test, questionnaires, and interviews which were developed independently and tested for validity & reliability. The analysis technique was the paired sample t-test and content analysis. The results of this study showed that the learning media was very eligible with a validation score reaching 88.1%. The result of the implementation of the final product of ChemiCa shows that there is an impact of using media on student learning outcomes (Sig. 0.000<0.05). Students' perception of the media are very good, learning media can increase their understanding of carbon compounds concepts, as well as their motivation to learn chemistry. This study implies that teachers can use augmented reality-based card game as a supplementary learning media to improve students' understanding of others relevant chemistry concepts and their environment literacy.

Graphical abstract



Keywords

Augmented reality
Carbon compounds
Card games
Environmental literacy
Learning media

Article history

Received 16 Nov 2022
Revised 30 Apr 2023
Accepted 15 May 2023
Available online 14 Jul 2023

Handling Editor: Nathalia R. Almeida

1. Introduction

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Pollution, intensification of raw materials, and poor waste treatment are the causes of environmental degradation [1]. The decline of environmental quality is influenced by various phenomena, such as natural disasters, the development of industrialization, and human actions. However, the lack of environmental literate society is the main factor in environmental degradation. Environmental literacy is the ability to apply deep understanding and abilities to environmental problems through the process of analysis, synthesis, evaluation, and decision-making as a community [2]. The lack of integration of environmental knowledge in learning causes low public environmental awareness [3]. Environmental knowledge itself has a close correlation with increasing environmental awareness [4].

A study on the environmental literacy profile of high school students conducted by Redhana, Suardana, & Selamat shows that the dimensions of student environmental knowledge are classified as medium level [5]. This knowledge dimension is related to students' cognitive processes, so it requires higher-order thinking skills (HOTS) processes. This is also in line with Nasution's research which shows that aspects of student environmental knowledge are still low [6]. Thus, the integration of environmental education into the learning needs to be developed. The addition of environmental content in learning is a way to do this.

The study conducted by Panjaitan et al. shows that most students are not able to implement their environmental literacy due to their lack of scientific literacy [3]. Scientific literacy supports the development of scientific thinking that supports the application of knowledge in everyday life. However, data shows that there are still many students in Indonesia who have difficulty integrating their knowledge with the surrounding phenomena [7]. This fact is reinforced by the existence of PISA data which shows the scientific literacy of Indonesian students only gets a score of 396, which is low and below the global average, which is 489 [8]. The results of the scientific literacy analysis can be an indicator of the low integration of knowledge in everyday life because scientific literacy is related to the application of science in life [9]. Therefore, it is necessary to strengthen the knowledge integration about everyday phenomena, especially environmental education to foster a sense of environmental concern [10,11].

One of the chemistry topics that are close to everyday life is carbon compounds. Carbon compounds focus on the discussion of alkane derivatives and the compounds that are discussed on this topic are related to everyday life [12]. Thus, this topic is suitable as a bridge to provide environmental education to students and strengthen the integration of their knowledge in everyday life. However, this material is still considered difficult by most students [13].

A study shows that more than 50% of students have low learning outcomes on carbon compounds [14]. Another study also showed that student learning outcomes did not achieve completeness on the carbon compound topic [15]. Other data states, that 70.83% of students still have learning outcomes that are below the minimum standard [16].

Several obstacles are experienced by students in learning carbon compounds. First of all, students are having difficulties understanding and remembering the structure of various functional groups [17]. Students also have difficulty understanding the structure of compounds because they are abstract, so there is a need for additional media in organic chemistry learning [18]. This is exacerbated by the learning of carbon compounds which has been dominated by teacher-centered learning with the lecture method. Finally, students become bored and less motivated in learning this topic. To deal with existing problems, learning media is needed to help understand carbon compounds independently and integrated with real-life examples around to improve students' environmental literacy.

According to constructivist theory, learning is a student activity in building knowledge from their interactions with the environment independently [19]. In the process, students are active in building their knowledge gradually through a series of processes, so knowledge is more meaningful. To assist students in building their knowledge, the learning media is needed to provide references in the construction of knowledge and clarify the concepts that are being built. The card game can be a suitable learning media for this [20].

The development of card games for chemistry learning itself has been widely carried out in chemistry topic [21-25]. In summary, the implementation of these developments in learning shows an increase in students' understanding. Card games can present a variety of learning processes that are more fun than conventional learning. Student involvement is increasing and improving student learning outcomes. Students are more active in constructing information, so they can improve their understanding. Students can also independently practice their understanding anywhere and anytime without a teacher. However, in previous studies, there were several shortcomings, such as the lack of molecular visualization, low-resolution images, and the lack of technology integration in the media.

Based on this, a card game-based learning media for carbon compounds equipped with augmented reality to support students' understanding of carbon compounds (ChemiCa) is designed. ChemiCa is a card game with a guest, collect, and win system that adopts a quartet card. On the back of the card is also linked a QR-Code which contains several compound information. The card game is then combined with augmented reality (AR) and provides insight into environmental literacy.

Augmented reality applications on learning media can improve understanding of an abstract topic [26]. AR can overcome this by providing visualizations that can be easily accessed by many people. The development of AR in chemistry learning itself has been carried out with various features and has a good impact on [27]. Thus, AR is added to the developed media. The purpose of this study was to develop learning media for carbon compounds based on augmented reality and environmental literacy and to find out student learning outcomes after using media, students' perceptions of the media, and their environmental insight.

2. Material and Methods

This research and development (R&D) focus on the product development and implementation. The product is a learning media of carbon compounds in the form of cards for high school students. This R&D research follows the ADDIE development model [28]. This model is suitable for developing learning media and learning instruments that are targeted, dynamic, and effective [29]. This model is also considered more rational and complete than the 4D development model [30]. Therefore, this research following Figure 1.

The ChemiCa development procedure following the ADDIE model is detailed as follows. In the first stage, several analyzes were carried out to see the urgency of developing the media created and to analyze the suitability of the media. The

literature studies were conducted by looking at several scientific articles and books related to the development of learning media for carbon compounds based on augmented reality and with an environmental literacy perspective. The characteristics of the media that will be presented are also studied, such as the form of card games and suitability to the competencies.

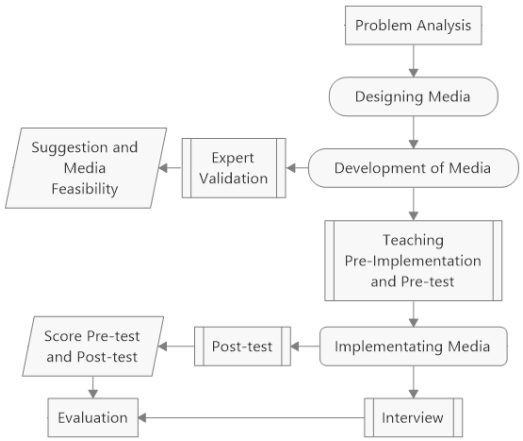

Fig.1. Research Flowchart.

At the design stage, the design of the media that will be made and the determination of how a media will be developed and implemented is carried out. In this step, the creation of several designs is also carried out, such as the creation of a ChemiCa card design, logo, container design, and the creation of a 3D carbon compound structure. Making 2D designs is done using CorelDraw 2018 software and making 3D structures using the Blender application. The structure of the compound refers to the ChemDraw 15.0 software.

At the development stage, the manufacture or realization of learning media products is carried out according to the design that has been made. The conceptual framework that has been made previously is developed until it is ready to be implemented. In this case, the development of ChemiCa has reached the stage of card printing and integration of augmented reality. AR was developed using the Assemblr Edu platform. The use of Assemblr Edu as an AR development medium has also been carried out in other studies and received positive responses [31]. Development through this platform is also relatively easy, fast, and can be integrated directly on a smartphone even if an update is made.

The material compiled in the media has passed the checking stage, so it can be applied in real situations. At the end of this development stage, media and material validation will also be carried out by several parties, such as teachers and experts. Development is not only carried out on the product but also on other accompanying components, such as instruments. Test questions and teaching media in the form of PowerPoint media were also validated by experts before being implemented. After the validation, media are adjusted based on the suggestions and criticisms that have been given.

At the implementation stage, the results of the final product development are then applied to the class to see the influence of the media in improving students' understanding. A one-group pre-test-post-test design study was conducted to assess this. One group of students was given a pre-test and then given treatment followed by a post-test to determine students' understanding. Additional data like interviews with students were also obtained to strengthen the findings. The research sample is a natural science student of class XII, one of the senior high schools in Mojokerto who has received material on carbon compounds through convenience sampling or availability sampling. One class which amounted to 30 people was given carbon compounds learning and equipped with ChemiCa media. Learning is carried out for two meetings (@90 minutes). The use of media was carried out seven times outside of class hours with an average of 30 minutes of play. Quantitative data were collected before treatment (pre-test) and after treatment (post-test). Then, the data were statistically analyzed using SPSS 26.0 Windows [32]. Qualitative data is the result of interviews related to media perceptions and environmental insights on five students who were voluntarily interviewed. Interviews were conducted after implementation in a semi-structured manner for ten minutes.

In this study, the data were collected through questionnaires, interviews, and test techniques. The questionnaire used was developed based on a Likert scale with a value range of 1 – 5 to indicate an assessment. The validation questionnaire developed includes (1) a material validation questionnaire, (2) a product validation questionnaire, (3) a test validation questionnaire, and (4) a teaching media validation questionnaire. The comments and suggestions obtained from this questionnaire are used as the basis for product improvement before testing. The interview technique used is a semi-structured interview which allows respondents to give answers freely [31]. The interview questions were developed from the aspect that the students wanted to assess. Tests to measure student learning outcomes are carried out through multiple choice questions on the topic of carbon compounds. The questions on the pre-test and post-test are different but are developed based on the same indicators. The developed instrument has been previously validated and improved according to the validator's suggestions. The questions used have been validated by experts with an assessment of 90%, which means it is very feasible [34]. The validity of the questions used was also checked with SPSS and all 15 questions in the multiple-choice pre-test-post-test proved valid. The reliability of the 15 questions was 0.617 in the pre-test and 0.656 in the post-test. The problem focuses on the naming, structure, and use of carbon compounds based on the competencies of carbon compounds.

In the last stage, namely evaluation, several analyzes were carried out to see the effect of using the media that had been developed. Data analysis was carried out on quantitative data using statistics. Quantitative data analysis includes (1) reliability and validity tests; (2) normality tests; and (3) paired sample t-tests. Some of the steps taken to perform the overall data analysis include the following steps. First, the calculation of the validity of the results of the questionnaire related to the topic, teaching media, media, and questions. The results of the questionnaire using the Likert scale provide interval data that can be calculated on average (score obtained/ideal score). The data can then be presented in the form of a percentage.

The students' test results were calculated for reliability and validity using a significance level of 5%. Both calculations were carried out on the students' pre-test and post-test data. Calculation of validity using SPSS through the Pearson bivariate correlation. The question is said to be valid if the value of t count > t table. After that, a reliability test was carried out on the questions using the Alpha Cronbach formula.

Second, an analysis of the test results was carried out. The

pre-test and post-test data were tested for normality. The data was said to be normal if the significance number reached 0.05 or more. Data testing was carried out using a significance level of 5%. Then, a paired sample t-test was conducted on the test result data to determine whether there was an effect of learning media on student learning outcomes. If the significance value is <0.05, it can be concluded that there is a difference in the average student learning outcomes. If the significance is < 0.05 then there is a difference, so ChemiCa media influences learning [35].

To strengthen the findings, an analysis of the results of interviews with several subjects was carried out. The qualitative data shows the perception of media use so that it can provide an overview of the influence of the media in improving students' understanding. In addition, the interview data also shows the environmental insight of the students. Data analysis was carried out through content analysis techniques. Through this technique, the interview data is coded and then conclusions are drawn to strengthen the quantitative findings. This generalization will lead to the conclusions of the research conducted [36].

3. Results and Discussion

ChemiCa Product Development Results: Augmented Reality-Based Card Game and Environmental Literacy Insight

The product created in this research is carbon compound learning media in the form of a card equipped with AR. This media contains several carbon compounds along with the characteristics and hazards of these groups. This game-based media is called Chemistry Card (ChemiCa). ChemiCa is played in groups of at least 2 players. ChemiCa is a card game that adopts a quartet card game system. The quartet card system in chemistry learning has also been noted to improve students' understanding in previous studies [21,22,24,37].

Fig. 2. ChemiCa Learning Media Products front and back.

The group of compounds in ChemiCa can be customized to the user, whether for students in college or high school. It makes ChemiCa a flexible and varied learning media. In ChemiCa, each card shows a chemical structure and name. Each group consists of four other compounds which are also displayed in front of card Figure 2.

On the front of the card is an AR marker that contains a clue to guess the cards. The AR displays 3D molecule images of the linked compounds. The addition of AR in this media is correlated with the benefits that can be provided in learning chemistry [27].

1. Can provide visualization and detail of object structures as well as simulations of their interactions that cannot be accessed through direct observation.
2. Can provide additional data about objects in the form of visual, written, or audio visual.
3. Can provide a digital simulation visualization experience.

This information can help players guess the group of compounds. By understanding the characteristics of AR, the group of compounds can be known, so that players can guess. Players can also learn about the uses and properties of a compound by guessing the compound after guessing the group. Players get clues from compounds that will be guessed from AR reading in Figure 3.

In the Figure 4, information related to toxicity, properties related to danger, and effects is displayed. Linking environmental education through hazard information can increase students' awareness of the environment [38]. Increased knowledge of the dangers of a compound adds to the cognitive dimension of students' environmental literacy. ChemiCa integrates carbon compounds with knowledge of the dangers of compounds in the surrounding environment. This knowledge becomes a bridge in developing students' environmental literacy [39]. This integration also helps students better understand the topic by providing integration of examples in real life with the topic presented. Indirectly, students form more understanding which leads to better memory.

The result of the development of media products is then validated by experts on the material and media aspects. The questionnaire used is a questionnaire with a Likert scale and contains aspects that are developed. Based on the results of the validation carried out by experts, the average percentage value for all aspects of product assessment was 88.1% which was within the very feasible criteria, so it can be concluded that the product can be used. However, there are some comments and suggestions given by the validator for media improvement.

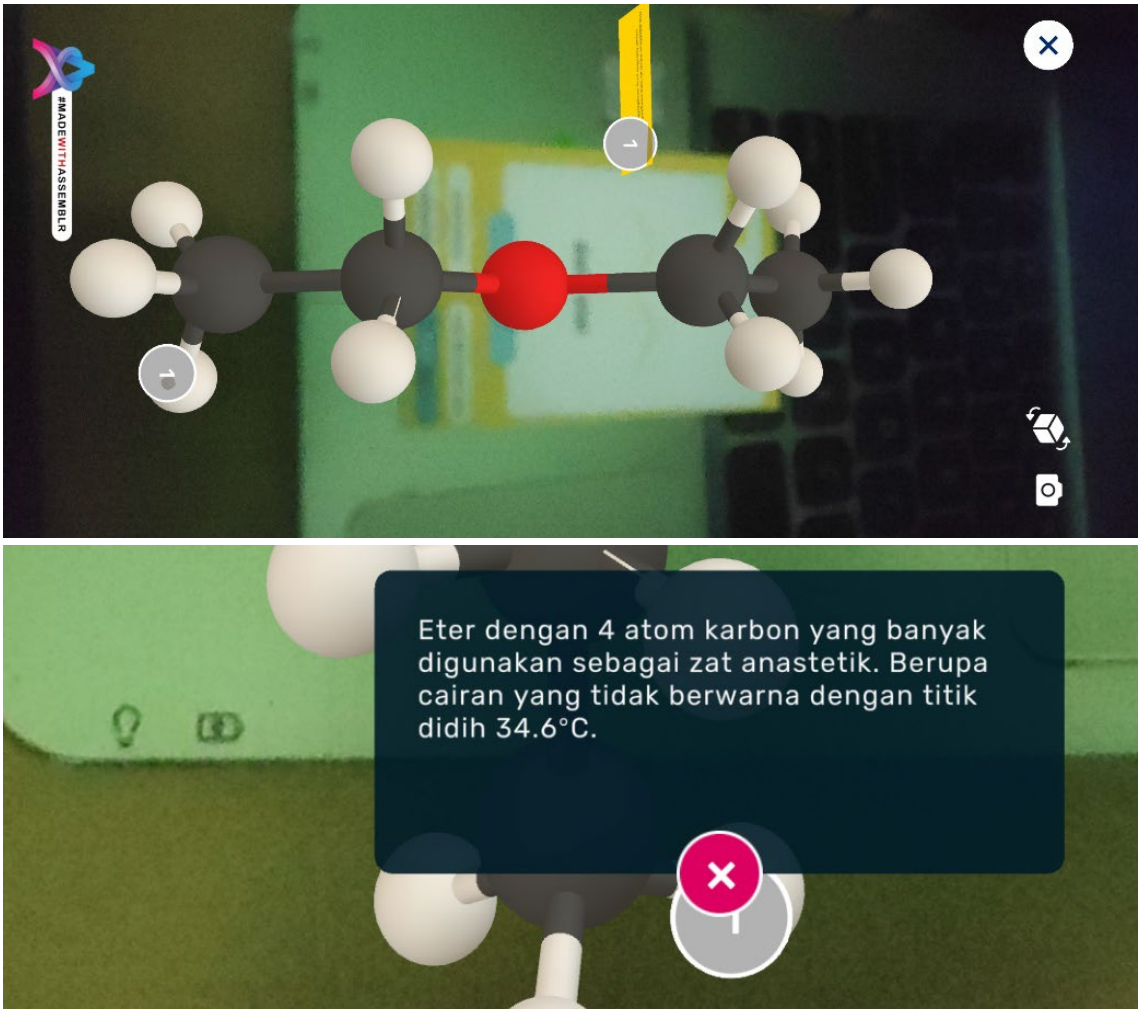

Fig. 3. 3D Molecular that is displayed and its clue.

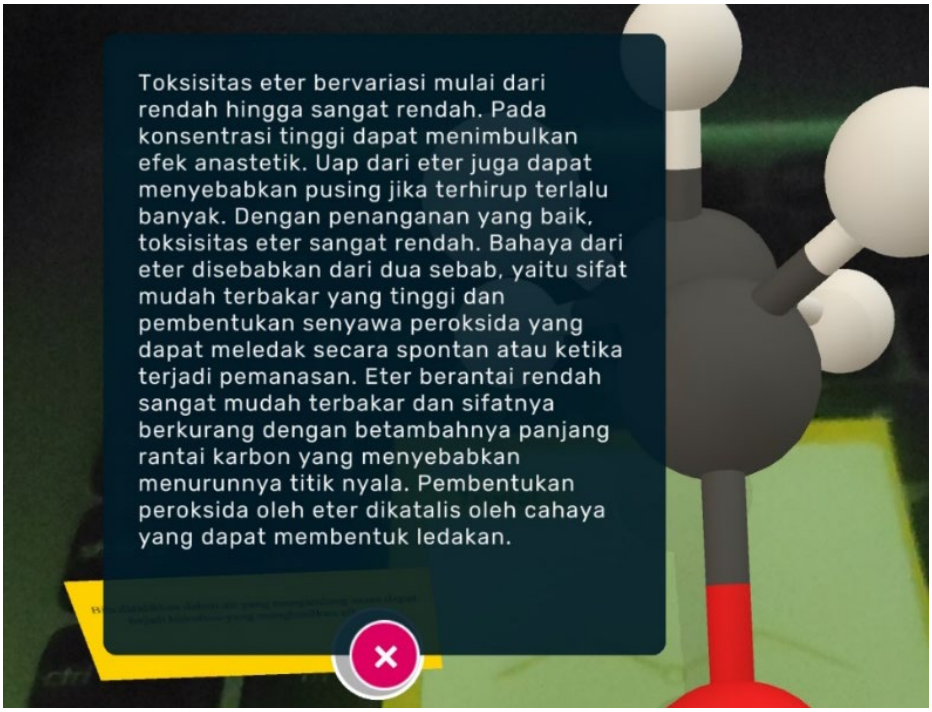

Fig. 4. Clue of the group compound on the front and back of the card as well as information on the dangers of the compound.

The Effect of ChemiCa Media on Student Learning Outcomes in Carbon Compounds

Before further analysis, the data from the pre-test and post-test were tested for normality through SPSS. The pre-test and post-test data were normally distributed with normality significance values of 0.130 and 0.103 (α>0.05). Next, a paired sample t-test was performed on the results of the pre-test-post-test. Through this test, it can be seen the difference in the pre-test-post-test data. The results of the calculation in Figure 5 showed that the significance level was 0.000 (<0.05).

Table 1. Paired sample T-Test result.

Pair	N	Mean	Std Deviation	Std Error Mean	df	T	Sig. (2-Tailed
Pre-Post	30	40.22	17.285	3.15594	29	12.745	0,000

There are significant differences in learning outcomes before and after being taught using media. Therefore, learning the topic of carbon compounds carried out with the help of media that has been developed influences student learning outcomes. There is a significant increase in student learning outcomes. This correlates with the provision of media that supports learning carbon compounds. Learning media helps explain something so the recipient can more easily understand it [40]. The same thing was found in a study conducted by Yerimadesi et al. regarding the use of media on the topic of carbon compounds. Learning media can improve students' understanding of carbon compounds [17]. Another study also showed increased student learning outcomes on the periodic system of elements through game media [41].

ChemiCa helps students to hone their skills by understanding the topic of carbon compounds by guessing compounds based on the clues given. Through this process, students are encouraged to understand the topic provided. ChemiCa supports iterative learning and is more fun and student focused. This is an alternative implementation of learning the case of carbon compounds which tends to be teacher-centered [15]. The presence of ChemiCa supports the process of building student understanding to be more enjoyable. The existence of a pleasant learning atmosphere can increase student learning motivation. The study by Dony et al. shows an increase in students' motivation when using game card media [42]. In the implementation of ChemiCa media, the subject has high enthusiasm.

Student enthusiasm reflects increased learning motivation. Learning motivation fosters passion, pleasure, and enthusiasm for learning, enabling students' strong desire to learn [43]. This encourages student activity during education. ChemiCa can create a competitive environment among peers that boosts student morale. The quartet card system encourages students to collect as many cards as possible through the guessing process so that students' activeness and understanding are encouraged to increase.

Increased student involvement can improve learning outcomes because students are more active in absorbing information [21]. Students can independently learn to use the developed card media. Students get to find and know the concepts of teaching topics [44]. Therefore, learning is not monotonous and is preferred by students [45].

Several obstacles occurred during the implementation of the research. First, there are smartphone limitations that can install the Assemblr Edu application as an AR marker scanner platform. These limitations are caused by minimum smartphone specifications and limited storage space. Storage limitations are most encountered during implementation. To overcome this, students take turns using devices that can install the ChemiCa application.

Second, ChemiCa is mainly used outside classroom learning as a different learning media. This provides obstacles in early implementation. The researchers formed a coordinator to carry out the game to overcome this. The performance of ChemiCa outside of learning hours is carried out during recess and after learning is complete. These implementation constraints can be used as a reference for future improvements. Furthermore, further research can be carried out regarding the ChemiCa media that has been developed.

Students' Perception of ChemiCa as a Learning Media for Carbon Compounds

Students' perceptions of the media are reflected in three main aspects: media, motivation, and learning. The data was obtained through semi-structured interviews with five respondents who had participated in implementing the media. In terms of media, ChemiCa is a learning media that can be accepted or followed by students. AR in ChemiCa provides a unique attraction for students because it can digitally bring up objects in the form of molecular shapes. Students generally rate this media well because it helps them learn and is enjoyable. From several participants, R2 firmly stated that ChemiCa media could help study carbon compounds because AR is interesting and easy to understand.

Q: “What do you think about ChemiCa media?”

R2: “good, helps study in alcohol, ether, ketone, ester. In the form of cards that can be played with friends as well. Exciting"

Q: “How does ChemiCa provide the AR?”

R2: “Interesting. Can bring up molecular pictures of the compounds on the card.”

Q: "What is the main attraction of this learning media?"

R2: “AR images of molecules. The picture is good, as it appears.”

Q: “What do you think about the ChemiCa gameplay?”

R2: “It's a quartet card game. So, it's quite understandable."

Several other responses related to ChemiCa media, such as helping in the study of carbon compounds (n=2), interesting media (n=2), AR is interesting because it can bring up molecules (n=4), interesting card design (n=1), and like a quartet card (n=3). However, there is also a response to ChemiCa's gameplay which is quite complex, making it difficult to follow. Moreover, some respondents stated that they were less proficient in chemistry and had difficulty following the game at the beginning.

In terms of motivation, students enjoy playing ChemiCa. Students feel happy when the game takes place. This shows that students experience an increase in learning motivation. In line with this, five respondents directly stated increased reason while using the media. From several participants, R1 said that ChemiCa media could increase learning motivation.

Q: "Did you enjoy the game presented?"

R1: “I enjoyed it very much.”

Q: “How was your motivation during learning using ChemiCa media?”

R1: "increased than usual learning, sir."

Q: "How do you feel while playing this game?"

R1: “it's nice to be able to play.”

Several other responses related to student motivation, such as enjoying the game very much (n=4), feeling an increase in motivation (n=5), and feeling the excitement of playing ChemiCa (n=2).

In terms of learning, students experienced an increased understanding of media use. The learning media presented provide material that is quite complete for students. Students can absorb the material contained in the media. Students get learning related to compounds, groups, structures, nomenclature, characteristics, and molecular shapes. Students also learn knowledge about AR and the dangers of a mix. From several participants, R1 stated that ChemiCa media got knowledge of carbon compounds.

Q: “What did you get or learn from using this media?”

R1: “Structures, groups, properties. In addition, from the AR, there is a molecular shape."

Q: “how is the topic presented in ChemiCa media.”

R1: “alcohol to ester. Then there are the structures and properties. Quite complete."

Q: “Has your understanding improved with this media?”

R1: “Yes, increase.”

Several other responses related to student learning, such as being able to learn carbon compounds (n=4), getting to know AR (n=1), the topic presented was quite complete (n=3), and students felt an increase in understanding (n=5).

In general, students' perceptions of the developed media were perfect. From three aspects, namely media, motivation, and learning, students experienced a positive increase. ChemiCa media helps in learning carbon compounds by providing visualization through AR. Students experience increased motivation and understanding using media.

Students' Perceptions of Environmental Aspects after Using Media

The ChemiCa media connects environmental insights regarding the hazards and problems that can be caused by the substances studied. By linking this, students gain additional insight to relate better what they learn to everyday life.

In general, most respondents stated that the media increase knowledge related to the environment. With this increase in learning, the respondent's concern for the environment increases. From several participants, R2 stated that ChemiCa media is vital in increasing environmental awareness.

Q: “Did your concern for the environment increase with the use of chemical media? How do you try not to throw away hand sanitizer carelessly?”

R2: “Yes, that's right, I care more about the environment because I know the negative effects of some substances around me. For example, I try to use hand sanitizer until it runs out so that I don't leave anything in the bottle so that the hand sanitizer doesn't pollute the environment."

Q: "The use of alcohol in hand sanitizers is common because it is considered to kill germs or bacteria, but because it contains methanol, some hand sanitizers are prohibited from circulating; why is that?"

R22: "Why are hand sanitizers banned because they contain methanol? Methanol has a bad effect on the environment, such as on the skin, which causes dry skin, and lack of hydration, and if consumed in excess, it can cause neurological disorders in the brain and blindness. In addition, methanol can cause nausea, vomiting, and headaches.”

From the results of these interviews, students know about the dangers of substances to the environment. This

encourages students to care more about the surrounding environment so that actions arise to preserve the environment. Several other responses from respondents were throwing the used hand sanitizer container in the trash according to the category (n=3), using the hand sanitizer according to its function (n=1), and methanol is a substance that is harmful to living things (n=4)

4. Conclusions

The product created in this study in the form of card learning media on AR-based carbon compounds and linking environmental literacy aspects can be categorized as feasible with a validation score reaching 88.1% so that the game card media (ChemiCa) can be implemented. However, some notes form the basis for future improvements in the developed media. The results of the implementation of the final ChemiCa product show significant differences in student learning outcomes before and after taught using ChemiCa media, so it can be concluded that there is an effect of using media on student learning outcomes. Students feel happy with the learning media, so it is alleged that their learning motivation increases, improving their learning outcomes. This is in line with students' perceptions of media that can help to learn and increase learning motivation. Therefore, student learning outcomes in the carbon compounds improve. On the other hand, students' insight into the environment increases, so their concern for protecting the environment also grows.

This research has implications to initial research that provides learning media on augmented reality-based carbon compounds with an environmental literacy perspective. Furthermore, other researchers can develop this research by applying a quasi-experimental design with group and control classes. Further research needs to pay attention to smartphone specifications, the number of people, and implementation time so that the study runs more smoothly.

Acknowledgments

Thank you to the Ministry of Education, Culture, Research, and Technology for assisting in funding this work through the Innovation Talent Scholarship for the 2021 Fiscal Year.

Author Contributions

AA has develop the concept of the research, giving visualization, investigating, and perform formal analysis. AA also become the writer of original draft. SR help to build the concept and methodology. SR also become supervision of this research and review and editing the final draft.

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How to cite this article

Ardyansyah, A.; Rahayu, S. *Orbital: Electron. J. Chem.* **2023**, *15*, 118. DOI: **http://dx.doi.org/10.17807/orbital.v15i2.17617**