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Development of LKPD Assisted by Augmented Reality (AR) Media on Chemical Bonding Materials to Improve Student Learning Outcomes

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A B S T R A C T

Chemical bonds are a concept that is often considered abstract by students because of the limitations of direct experience to understand the occurrence of chemical bonds. This research developed a Student Worksheet (LKPD) assisted by Augmented Reality (AR) media that allows students to see and understand the shape of chemical bonds in 3D animation. The development process of this LKPD follows the modified Research and Development (R&D) method of Borg and Gall, consisting of three stages: preliminary study, development, and testing. The results of the validation test get a ≥4 mode which means that it is practical from the validation sheet. The results of the practicality test obtained percentages of 80% and 90%, meaning practical and very practical, based on student response questionnaires and student observation sheets. The results of the effectiveness test showed that a significant value of 0.000 was less than 0.05 indicating a significant average difference in student learning outcomes. Research shows that the use of LKPD assisted by AR media can improve students' learning outcomes on chemical bonding materials.

1. Introduction

Education has a huge influence on every person and society. Because education can bring improvement and change to us. Education is an experience in formal or non-formal programmatic learning with the aim of improving the abilities of everyone. The formal education that we will take before continuing to college is Senior High School (SMA). While in high school, students will learn various sciences, one of which is chemistry. According to Ansori, chemistry is a science that studies the transformation of matter into other forms, the properties of matter, and the structure of matter (Nur, 2022). Chemistry is often said to be difficult compared to other sciences. The reason chemistry is considered difficult is because there are many

terms or formulas in chemistry that most people don't know, and because chemistry is abstract so it's not easy to imagine (Chang, 1993).

Chemical materials themselves contain many concepts, are abstract and very difficult to apply in social life (Safitri et al., 2018). Chemical bonds are one of the abstract chemical materials because it requires the ability to be able to see how an atom forms into chemical bonds. Based on research at SMA Negeri 18 Surabaya, as many as 31% of students answered that chemical bonds are unattractive chemical materials. The unattractiveness of chemical bonds is because the material is abstract with 51% of students answering. Because chemical bonds are abstract materials and cannot be observed directly during the learning process, this leads to low learning outcomes for students. In the results of observations conducted at SMA Negeri 1 Pamotan, the learning outcomes of class X MIPA students in chemical bonding materials are still relatively low, namely out of 35 students, only 13 students have achieved learning completeness (Lestari, 2019). In addition, at SMK Negeri 1 Gombong, the average score of students' learning outcomes in the cognitive realm was 58.98 out of 36 students, only 9 people (25%) managed to achieve completeness in the competency test at competency standard 1, while 27 other students (75%) have not achieved this completeness (Sugiarsih, 2022).

Based on the results of the pre-research at SMA Negeri 18 Surabaya, students had difficulty learning chemical bond material in the coordination covalent bond sub-material with a total percentage of 49%, followed by covalent bond sub-material with a percentage of 40% and followed by ion bond sub-material with a percentage of 11%. This is because chemical bonding materials are abstract, if not studied. The low learning outcomes of students are since the material on chemical bonds is difficult to understand and is abstract. In addition, as many as 64% of students said that during chemistry learning they paid less attention to the teacher because of the lack of use of media in learning which made them feel bored (Nurillah & Purwanto, 2023). In addition, it is because of its abstract chemical bonding nature and the depiction of the chemical bonding process that is not 2D or 3D (Asri & Dwiningsih, 2022).

The existence of the above problems requires the use of a medium that can help students understand the concept of chemical bonds which are abstract and can provide visuals of the process of forming chemical bonds (Rahmi et al., 2022). The development of media continues to increase with the times. The use of media also increases the spirit of learning, increases motivation, increases interest, and provides a positive psychological impact on students (Basri & Sumargono, 2018). Learning media can be divided into visual media, audio media, and audio-visual media. One type of media that can be used in the learning process is visual media (Rahim, 2020). The use of AR has shown great potential as a learning tool, offering an interactive and engaging way to visualize complex concepts such as chemical bonding.

According to the results of research conducted by (Nurillah & Purwanto, 2023), chemical bonding materials can be visualized with the presence of AR media. AR is a medium that can project virtual objects in two-dimensional (2D) or three-

dimensional (3D) form into a real environment (Pamoedji, 2017). AR media can be created or developed through software, namely Unity. Unity is a software engine that can create three-dimensional (3D) objects, sounds, textures, and more. Unity is a software engine that can process various types of data, such as 3D three-dimensional objects, sounds, textures, and more. Many studies state that the use of media-assisted learning such as AR media can be developed. As research conducted (Nurillah & Purwanto, 2023) on student learning outcomes in the use of AR media and the use of PowerPoint media. The results were obtained that there was a significant difference in student learning with the use of the two media. So that the use of AR media is effective in improving students' learning achievements. Other research conducted (Rahma et al., 2024) in science learning, the use of LKPD assisted by AR media can be applied, because it makes abstract objects into two-dimensional (2D) and three-dimensional 3D animations. The use of these media also makes the learning environment more modern.

LKPD is a learning tool that can facilitate the process of teaching and learning activities, a tool that helps interaction between educators and students, a tool that helps in improving students' learning activities and outcomes (Muslimah, 2020). Thus, the existence of LKPD is expected to make students active during learning activities. From several studies that have been conducted, LKPD with the existence of AR media can make abstract objects into animations that can improve students' understanding of concepts. However, at SMA Negeri 1 Bangkinang Kota, LKPD which is not supported by AR media has not been able to develop collaborative learning skills in groups (Yuliandriati et al., 2019). This is because the questions in the LKPD have not directed students to be able to understand concepts in depth, the lack of variety of questions in the LKPD because the LKPD only contains dots or multiple-choice questions In addition, the content of the LKPD is also not in line with the material in the textbook, causing a gap between what is taught in class and what should be studied by students in more depth (Wahab & Rosnawati, 2021).

Based on the problems above, in learning chemical bond material, there is a need for media that can help students understand abstract concepts of chemical bonds, and make students not bored during chemical bond learning such as the use of AR media that can be packaged using LKPD. Therefore, the researcher conducted research on the Development of LKPD Assisted by AR Media on Chemical Bonding Materials to Improve Student Learning Outcomes.

2. Methodology

The design used in this study is guided by the research and development steps (Research and Development), the process or steps to develop a new product or improve an existing product, as well as that can be accounted (Sukmadinata, 2016). Which is modified from the ten steps of research and development by Borg and Gall. In this R&D method, there are 3 stages, namely the preliminary study stage, the development stage, and the testing stage. The research design chart is presented in Figure 1. below.

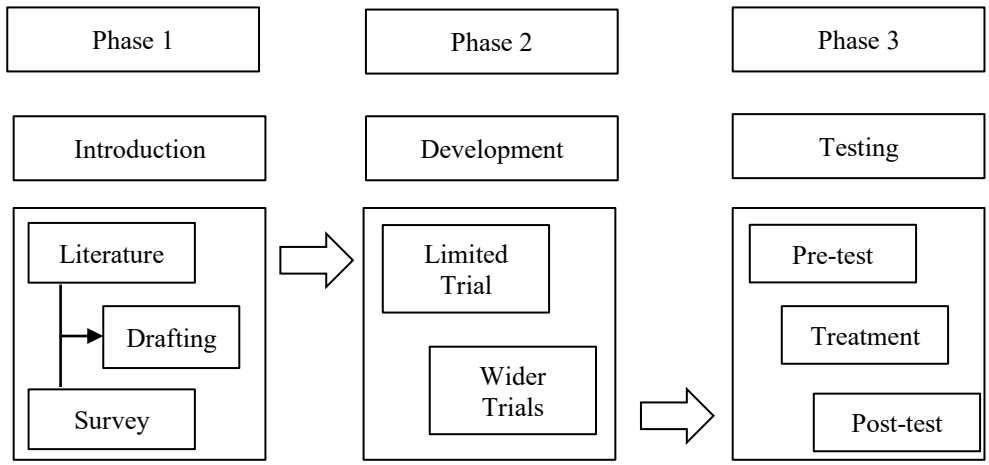

Figure 1. Research Design

In this study, the data obtained will be analyzed qualitatively and quantitatively. Qualitative data analysis is obtained from criticism and suggestions from reviewers and validators which will later be used to improve the media. Media validation calculation using the Likert scale as shown in Table 1. below.

Table 1. Likert Scale Score

Score	Statement
1	Invalid
2	Less Valid
3	Quite Valid
4	Valid
5	Highly Valid

Validation data is ordinal-scale data that can be analyzed by determining the mode of each aspect or indicator being assessed. An aspect is declared valid if it has mode ≥4, while an aspect that has mode <4 is declared invalid. If there are aspects that do not meet the valid criteria, it is necessary to revise and revalidate them until these aspects meet the set standards (Lutfi, 2021).

The calculation of the student response questionnaire uses positive and negative statements by giving "Yes" or "No" answers. Scoring is based on the Guttman scale score in Table 2. below.

Table 2. Guttman Scale Score

Response	Answer	Grade/Score
Positive	Yes	1
	No	0
Negative	Yes	0
	No	1

(Riduwan, 2015)

The data obtained will be analyzed using the formula:

$$\text{Response Percentage} = \frac{Number\ of\ Scores/\ Question}{Number\ of\ Respondents} \times 100\%$$

The results of the response questionnaire from students will be used to determine the practicality of AR media. The results of the student response questionnaire were then analyzed using Table 3. below.

Table 3. Practicality Criteria

Percentage	Criterion
0% - 20%	Impractical
21% - 40%	Less Practical
41% - 60%	Quite Practical
61% - 80%	Practical
81% - 100%	Very Practical

(Riduwan, 2015)

Based on Table 3., above LKPD assisted by AR media can be said to be practical if the assessment of students' responses obtains practical criteria with a percentage of $\geq 61\%$.
The calculation of the results of students' observations uses the following formula.

$$\textbf{Percentage of Implementation} = \frac{Number\ of\ Activity\ that\ Appears}{Total} \times 100\%$$

The results of the calculation of student activity data are then interpreted into the criteria in Table 4. below.

Table 4. Practicality Criteria

Percentage	Criterion
0% - 20%	Impractical
21% - 40%	Less Practical
41% - 60%	Quite Practical
61% - 80%	Practical
81% - 100%	Very Practical

(Riduwan, 2015)

Based on the presentation of the practicality criteria above, it can be interpreted that the results of student observation can be said to be practical and support the results of the participant response questionnaire if student activities with practical criteria are obtained or a percentage of $\geq 61\%$.
Data on student learning outcomes was obtained from the results of pre-test and post-test. To obtain the results of students' learning scores, it can be written with the following formula:

$$\textbf{Score} = \frac{Score\ Obtained}{Maximum\ Score} \times 100\%$$

After the pre-test and post-test scores are obtained, then an analysis is carried out to determine the improvement of student outcomes using the following methods:

a. Normality Test
The normality test is carried out to find out whether the data obtained is normally distributed or not. There are two commonly used types of tests, namely Kolmogorov-Smirnov for large samples and Shapiro-Wilk for small samples (<50). In this study, the Shapiro-Wilk test was used because the number of data was less than 50, with calculations using SPSS. Decision-making is based on significance values, i.e. data is said to be normally distributed if the significance value is ≥ 0.05, and not normally distributed if the significance value is < 0.05 (Sujarweni, 2015). If the data produced is normally distributed, then the test used is the T test and if the data produced is not normally distributed, then the test used is the Wilcoxon test.

b. Paired Test Sample t-test (T-test)
The paired sample t-test is used to find out if there is an average difference between two data from the same sample (Sujarweni, 2015). In this study, t-tests were carried out on the results of the pretest and posttest in the experimental class using SPSS. The steps include the formulation of a hypothesis, namely H0 states that there is no difference in the average learning outcomes between the pretest and posttest, while Ha states that there is a difference. The decision is taken based on the significance value, where H0 is rejected if the value sig. < 0.05 and accepted if the sig. value > 0.05. If H0 is rejected, it is concluded that there is a difference in the average learning outcomes, which means that LKPD assisted by AR media on chemical bonding materials is declared effective. On the other hand, if H0 is accepted, then there is no significant difference, so the LKPD is declared ineffective.

c. Uji Wilcoxon Signed Rank
The Wilcoxon Signed Rank test is used to find out if there is a difference between two interconnected samples, with a data type in the form of intervals or ratios that are not normally distributed (Sujarweni, 2015). The test was carried out using SPSS through several stages, starting from the formulation of a hypothesis: H0 stated that there was no difference in the average learning outcome between the pretest and posttest, while Ha stated that there was a difference. Decision-making is based on significance values, where H0 is rejected if the value sig. < 0.05 and accepted if sig. > 0.05. If H0 is rejected, then there is a significant difference between the results of the pretest and posttest, which shows that LKPD assisted by AR media is effectively used. On the other hand, if H0 is accepted, then there is no significant difference, so the LKPD is declared ineffective.

3. Results and Discussion

This activity was carried out by giving a pre-research questionnaire in class XI of SMA Negeri 18 Surabaya. The field survey was carried out by providing a pre-research questionnaire. From the results of the pre-research questionnaire conducted in class XI of SMA Negeri 18 Surabaya, it showed that as many as 60% of students did not like chemistry subjects. Then, the chemical bonding material

was also not interesting for them with 31% of students answering. Meanwhile, as many as 29% of students answered ordinary. Students thought that chemical bonding material was abstract material with 51% of students answering. Then, one of the sub-topics of chemical bonds that they found difficult was covalent bonds of coordination with 49% of students who answered, covalent bonds with 40% of students who answered, and ion bonds with 11% of students who answered.

Most of the learning resources that students have are only package books and LKPD. Students who answered the package book were 60% and students who answered the LKPD were 29%. With the learning resources they have, as many as 60% of students say they cannot understand chemistry material. Their learning resources were also not interesting to read with 54% of learners answering. Meanwhile, 37% of students answered that the LKPD contained only questions and 34% of students answered the LKPD containing questions and material in general. In addition, the use of media in chemistry learning also often only uses power points with 63% of students answering and 37% of students answering the board. As many as 86% of students answered that they wanted a medium in chemistry learning that was full of pictures or animations.

The creation of LKPD began with designing a storyboard that included a cover and contents according to the concept of chemical bonds. The three LKPDs are arranged based on different subchapters, namely ion bonds, covalent bonds, and coordination covalent bonds. Each has a different cover with a corresponding title and image. The contents of the three LKPDs are uniformly arranged, including instructions for use, concept maps, and adapted to the Discovery Learning model, as shown in Figure 2 below.

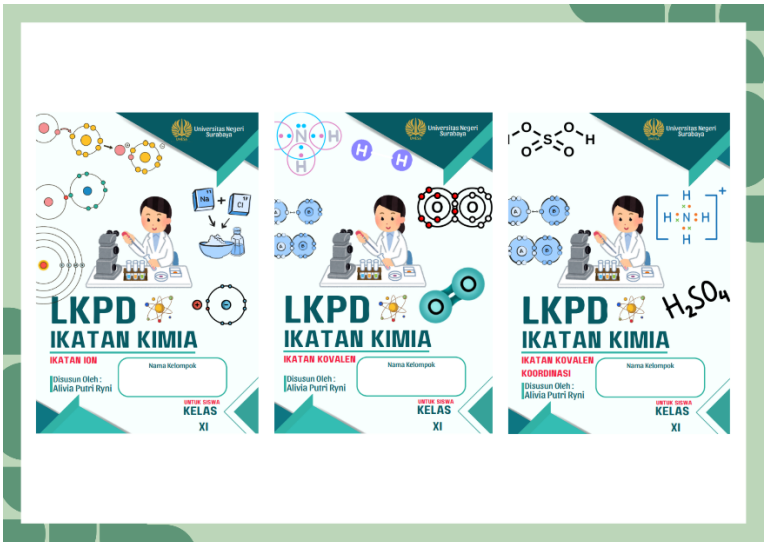

Figure 2. The Third LKPD Based on the Subchapter

Media-assisted LKPDs designed based on chemical bond subchapters have the advantage of helping students understand the material visually and systematically. An attractive cover display that fits each type of chemical bond can increase students' interest in learning. The content of the LKPD, which contains instructions

for use, concept maps, and is prepared with a Discovery Learning approach, encourages students to actively explore the material, think critically, and build understanding independently. This LKPD not only clarifies abstract concepts but also fosters student engagement and independent learning.

The results of students' work with media-assisted LKPD show that the learning tool can help students understand chemical bonding material more easily and interestingly, as shown in Figure 3 below, especially student work on the sub-chapter of covalent bonding material coordination.

Figure 3. Results of Student LKPD in the Coordination Covalent Bond Subchapter

Based on the LKPD, it shows a clear cover with the title of the subchapter that makes the student focus that they will study the material as well as the fill column for identity, then shown a learning activity sheet consisting of learning objectives, introduction, data collection, data processing, verification, and conclusion. This LKPD provides a clear flow of direction so that students can be well directed and expected to be able to understand the material well, considering that the mechanism of the LKPD flow is directed starting with observation to the thinking process and generalization. This process provides real impetus for students to be able to think in a process and provide structured answers based on the mechanism provided.

The preparation of product drafts begins with planning by creating an LKPD storyboard and AR media. Furthermore, from the storyboard, an initial draft will be obtained which will then be reviewed and improved again. Then validation is carried out by media experts and material experts. The following Table 5., Table 6., Table 7., and Table 8. of the results of LKPD validation and AR media.

Table 5. Ion Bond LKPD Validation Results

No.	Validity	Mode	Criterion
1.	Content Validity	4	Valid
2.	Construct Validity	4	Valid

Table 6. Validation Results of Covalent Bond LKPD

No.	Validity	Mode	Criterion
1.	Content Validity	4	Valid
2.	Construct Validity	4	Valid

Table 7. Validation Results of the Coordination Covalent Bond LKPD

No.	Validity	Mode	Criterion
1.	Content Validity	4	Valid
2.	Construct Validity	4	Valid

Table 8. AR Media Validation Results

No.	Validity	Mode	Kriteria
1.	Content Validity	4	Valid
2.	Construct Validity	4	Valid

Based on the validation results on the validity of the content and the validity of the construct, the LKPD on the ion bond, covalent bond and covalent bond of coordination is known that each aspect assessed has mode 4, which is valid. Based on the validation results on the validity of the content and the validity of the AR media construct, it also gets mode 4, which is valid. So that the LKPD in ion-bonding, covalent bonding, and covalent bonding materials is said to be valid. Likewise, AR media is also said to be valid.

Limited Trial

A limited trial was used to determine the results of the practicality and effectiveness of LKPD assisted by AR media. Practicality was obtained from the results of student observation and student response questionnaires. The following is a table of student observation results and a table of student response questionnaires.

Table 9. Results of Student Observations

Meeting	Observation Results	
	Relieve	Irrelevant
Meeting 1 (LKPD Ion Bonds)	91%	9%
Meeting 2 (LKPD Covalent Bonds)	92%	8%
Meeting 3 (LKPD Covalent Coordination Association)	91%	9%
% Average	91%	9%

Based on Table 9., in the first meeting the relevant activities carried out by students were 91%, in the second meeting as much as 92% and in the third meeting as much as 91%. Then the irrelevant activities carried out by students in the first meeting were 9%, in the second meeting as much as 8% and in the third meeting as much as 9%. So that the average relevant activity gets a score of 91% which can be said to be practical.

Table 10. Results of Student Response Questionnaire

No.	Purpose	Percentage	Criterion
1.	Obtaining the level of interest of students in LKPD assisted by AR media	83%	Very Practical
2.	Gain a level of ease of understanding chemical bonding materials with the help of AR media	80%	Practical
3.	Describe the level of ease of operating AR media	72%	Practical

Based on Table 10. above, each destination has practical criteria. To obtain the level of interest of students in LKPD assisted by AR media, an average percentage of 82% was obtained, which means that they are very active. To obtain the level of ease of understanding chemical bonding materials with the help of AR media, an average percentage of 79.95 was obtained, which means practical. To describe the level of ease of operating AR media, an average percentage of 71.4 is obtained, which means practical.

The next step is the effectiveness obtained from the learning results of pre-tests and post-tests of students when they have not used and after using the media. These pretest and posttest questions are multiple-choice questions with a total of 20 questions, consisting of 5 ion bond questions, 10 covalent bond questions, and 5 coordination covalent bond questions. After the students' learning results are obtained, a normality test is carried out, to find out whether the data obtained is normal or abnormal. Because the data on the results of this pre-test and post-test is less than 50, this normality test uses the Shapiro wilk test. The following is a table of the results of the normality test pretest and posttest of students.

Table 11. Pre-Test and Post-Test Normality Test Results

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-Test Learning Outcomes	.167	35	.015	.927	35	.024
Post-Test Learning Outcomes	.171	35	.011	.908	35	.006

a. Lilliefors Significance Correction

In Table 11. above, the results of the pre-test normality test with a sig value of 0.024 and post-test with a sig value of 0.006 are obtained. The sig result obtained was less than 0.05. So that the data produced is not distributed normally. Because the data is not normally distributed, the next test used is the Wilcoxon signed rank test. The Wilcoxon signed rank test was used to determine the average difference of two related samples. The following is a table of Wilcoxon signed rank test results.

Table 12. Wilcoxon Signed Rank Test Results

Test Statistics[a]	
	Learning Outcome Post-Test – Learning Outcome Pre-Test
Z	-5.183[b]
Asymp. Sig. (2-tailed)	.000
a. Wilcoxon Signed Ranks Test	
b. Based on negative ranks.	

Based on Table 12. of Wilcoxon signed rank test results, the result of the sig value is 0.000 which means that this result is less than 0.05. So that, H_0 rejected, and H_a accepted, which means that there is a difference in the average score of students' learning outcomes in the pretest and posttest at the time before the use of LKPD assisted by AR media and at the time after the use of AR media. Based on these results, it is known that LKPD assisted by AR media can be said to be effective. This is in accordance with (Rahmah & Vitoria, 2025) which states that the use of AR media has a significant effect on student learning outcomes.

4. Conclusion

Based on the results of the study, LKPD assisted by Augmented Reality (AR) media has been proven to meet the eligibility criteria as a learning tool. In terms of validity, this LKPD has gone through a content assessment process and constructs showing suitability for learning objectives and integration between its components. This shows that the LKPD is suitable for use in the learning process. In addition, in terms of practicality, this LKPD is considered easy for students to use and can support learning activities. Positive user responses indicate that this LKPD can be applied practically in the classroom. Furthermore, in terms of effectiveness, the use of AR-assisted LKPD has a positive impact on improving student learning outcomes. This shows that the learning media can support a meaningful learning process and help students understand the material better. LKPD assisted by AR media is a valid, practical, and effective learning tool to be used in improving the quality of the teaching and learning process in elementary schools, especially in materials that require high visualization and interaction.

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