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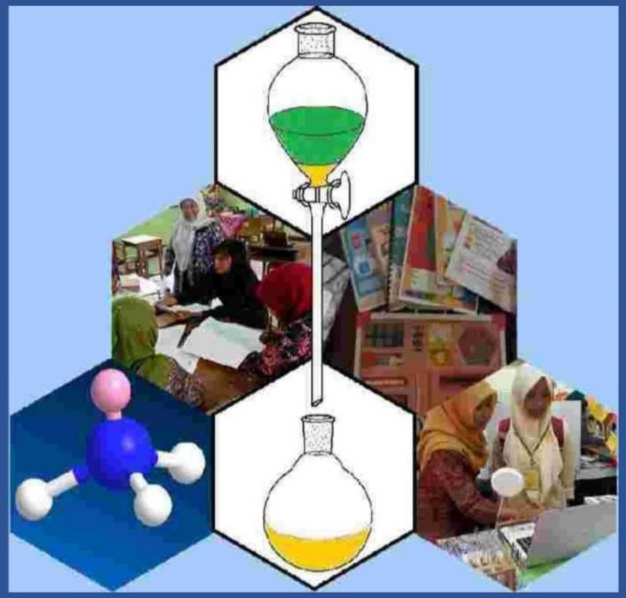

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DEVELOPMENT OF AUGMENTED REALITY-ASSISTED INTERACTIVE STUDENT'S WORKSHEET ON THE TOPIC OF MOLECULAR SHAPE

Filmonia Greslita Bili[1], Johnsen Harta*[2]

[12]Program Studi Pendidikan Kimia, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Sanata Dharma

*Corresponding author: johnsenharta@usd.ac.id

Abstract. *Chemistry learning at SMA Negeri 1 Kalasan still used conventional teaching materials. Teachers have never developed and used interactive LKPD. Molecular shape is one of the topics that is considered to be difficult, abstract, and challenging, so teaching materials are strongly needed that can visualize the concept well, one of them through using Augmented Reality technology. This research aimed to: (1) create product that fulfill the development feasibility criteria and (2) find out the response of students to the product during trial. This study was Research and Development (R&D) that refers to the 4D development model which has been modified into 3D, namely Define, Design and Develop. The instruments used in this study were interview sheet, survey questionnaire, validation sheets, questions item in the product, and questionnaire for students' response to the product. A number of 10 students of X MIPA class were selected through purposive sampling technique as research sample. The research data obtained were analyzed descriptively. The result showed that : (1) product has fulfilled the criteria of being very feasible including to be very valid with average percentage of 87%, very effective with average score of 99 that also supported by the acquisition of average percentage of completeness of working on questions of 97%, very practical with average percentage of 93%; and (2) students' response to the product is very good. The average percentage of student's responses per aspect item in the questionnaire was 92.81%. About 70% students stated that product is interesting and easy to understand.*

Keywords: *Interactive student's worksheet, Augmented Reality, Molecular Shape*

INTRODUCTION

In this digital era, one of the government's efforts to improve the quality of education is by implementing the 2013 Curriculum. The Curriculum aims to prepare Indonesian children to have the ability to live as individuals and citizens who are faithful, productive, creative, innovative, and able to contribute to life social. The use of Curriculum in schools requires teaching staff to further improve their performance in the form of knowledge, skills, and attitudes [1].

Chemistry is one of the subjects studied by students in high school, which is also a basic science, especially studying the existence of matter in terms of structure, the properties of matter, and their changes as well as the energy that accompanies these material changes [2]. One of the chemistry topics at the high school level is molecular shape. Molecular shape is a chemical science that describes the position of atoms in a molecule which is explained using various approaches, for example molecular orbital theory, crystal field theory, and electron pair repulsion theory [3].

Chemistry learning is very closely related to teaching materials. In the learning process, chemistry teaching materials are one of the learning support tools used by teachers and students in schools [4]. One of the teaching materials is the Student Worksheet (Lembar Kerja Peserta Didik = LKPD). LKPD is teaching material that contains brief material descriptions of chemistry topics, practice instructions, and practice questions that make it

easier for students to understand chemistry learning concepts [5].

The use of teaching materials in the form of LKPD in chemistry learning will be more interesting and enjoyable if combined with current technological advances. In research on the development of LKPD conducted by Nurafni & Azhar [5] using 3D modeling on molecular shape, the material had a very high level of validity and practicality. Apart from that, research conducted by Hurrahman *et al.*, [6] with the help of Augmented Reality (AR) technology on the topic of molecular shape is very valid and can be used without improvement. AR is an application that combines the real world with the virtual world in two-dimensional or three-dimensional form which is projected in a real environment at the same time [7]. The advantages of using AR are that learning can be more interactive, its use is effective, and can be implemented widely in various types of media. It doesn't cost much to make and it is easy to operate. One AR application is Assembler Edu, this application has the advantage of being based on visuals, images and 3D animation to attract attention and trigger curiosity, especially for students [8].

Based on the results of interviews with chemistry teachers at SMAN 1 Kalasan, Yogyakarta was obtained a few information that teachers had never used interactive teaching materials assisted by AR on the topic of Molecular Shape. This is supported by the results of the student survey, namely 72.8% with 67 students have never used interactive LKPD and 27.2% with 25 students have used interactive LKPD on the topic of chemical bonds and other subjects. This is also supported by the results of a student survey, namely 96.7% with a total of 89 students have never used teaching materials assisted by AR and 3.3% with a total of 3 students stated that they had used them.

Besides that, the result of interview with chemistry teachers at SMAN 1 Kalasan, the topic of molecular shape is a topic that is quite challenging for students. This is because students learn with limitations such as using 2D images and organic molymods and also difficult to imagine the real shape of a molecule. Judging from the abilities of students in all Class X MIPA students, namely 79.3% stated that the topic was difficult and 20.7% stated that the topic could be followed well. The causes of difficulties found from the results of student surveys are various, such as not understanding the concept of molecular shape, the names of molecular shapes are difficult to remember, it is difficult to distinguish between shapes and characteristics, because if the bonds are different, the shape will be different. This is in line with research by Ristiyani & Bahriah [9], who concluded that molecular shape material is quite difficult to understand because-it includes the concepts of bonding electron pairs, lone electron pairs, bond lengths, electron pair repulsion forces, and bond angles as a result of repulsive forces electron pair.

Based on this description, students have difficulty imagining the real structure of molecules when presented in 2D form. To overcome this, simpler teaching materials can be developed with 3D visualization of molecular shapes displayed by AR technology in teaching materials. In this research, researchers developed new teaching materials, namely interactive LKPD assisted by AR on molecular form material. This is because as reported that teaching materials with the help of AR technology-based media can increase visual-spatial intelligence and facilitate students' understanding of abstract chemical concepts [10].

METHOD

This study is a Research and Development (R&D). This research refers to the 4D development model which has been modified into 3D, namely Define, Design and Develop [11]. The product resulted from this research is an interactive worksheet assisted by AR on the topic of molecular shapes. Other instruments also used to support this research were product questions and questionnaires for respondents to assess the product. The product and all research instruments were validated and assessed by three validators.

After revising the product and supporting instruments, then limited trials were carried out. This research was carried out at SMAN 1 Kalasan. The research was carried out on even semester of the 2022/2023 academic year. The population taken were all students in class X MIPA SMAN 1 Kalasan who were then selected by several representatives as research samples. The research sample consisted of 10

students from 4 classess randomly selected by chemistry teachers with different cognitive abilities. Products and all instruments were analyzed descriptively. Information regarding data analysis can be described as follows.

Analysis of Product's Validation Result

The result of the product validation sheet were analyzed descriptively. Validation sheet analysis can be calculated using the average score from validators which will be used to determine the feasibility and validity of the product. Assessment of product feasibility and validity can be calculated using formula 1 according to Saski & Sudarwanto [12] as follows.

$$\text{Percentage} = \frac{\text{Total of obtained score}}{\text{maxium score}} \times 100\% \quad (1)$$

The final percentage value is the final average validation score from each validator. The final percentage value can be found using formula 2, then the level of eligibility criteria and validity category is determined based on Table 1.

$$\text{Percentage} = \frac{Va_1 + Va_2 + Va_3}{n} \quad (2)$$

Notes:

Va_1 : score from validator 1
Va_2 : score from validator 2
Va_3 : score from validator 3
n : numbers of validator

The final percentage value obtained from the product validation results is used as the feasibility and validity value of the product.

Table 1 Eligibility and Validity Criteria of Product

Percentage (%)	Eligibility Criteria	Validity Criteria
76-100	Very eligible	Very valid
51-75	Eligible	Valid
26-50	Uneligible	unvalid
0-25	Very uneligible	Very unvalid

Source: Arikunto [13] dan Arikunto [14]

Analysis of Validation Result of Questions Item in Product

Instrument validation was carried out to determine the validity of the questions contained in the AR-assisted interactive LKPD. Testing the validity of each questions item was carried out using the Aiken's V test [15], as shown in formula 3.

$$V = \frac{\Sigma s}{n(c-1)} \quad (3)$$

Notes:

$S = r - l_0$ (r = score from validators); l_0 = lowest score
n = numbers of validators
c = maxium score

The validity criteria of the questions created are based on the Aiken's V scale as seen in Table 2.

Table 2 Validity Criteria of Questions Item

Aiken's Coeficient	Validity Criteria
$V > 0{,}80$	Very valid
$0{,}40 < V \leq 0{,}80$	Medium
$V \leq 0{,}40$	Unvalid

Source: Retnawati [15]

Analysis of Validation Result of Questionnaire Sheet

The results of the response questionnaire validation sheet were also analyzed descriptively. Analysis of response questionnaire sheets can be calculated using the average score from validators. This assessment is calculated using the formula 4 according to Purwanto [16] as follows.

$$\text{Percentage} = \frac{\text{Total of obtained score}}{\text{maxium score}} \times 100\% \quad (4)$$

The final percentage value is the final average validation score from each validator. The final percentage value can be found using formula 5 then the level of validity criteria is determined based on Table 3.

$$\text{Percentage} = \frac{Va_1 + Va_2 + Va_3}{n} \quad (5)$$

Notes:

Va_1 : score from validator 1
Va_2 : score from validator 2
Va_3 : score from validator 3
n : numbers of validator

Table 3 Validity Criteria of Questionnaire

Percentage (%)	Validity Criteria
86-100	Very valid
71-85	Moderate
51-70	Unvalid
0-50	Very unvalid

Source: Akbar [17]

Analysis of Student's Answers

Based on the test results of student's answers are analyzed to identify students' understanding. A score was given to each student's answer as a scoring guide. The data obtained from the test is calculated using formula 6 to obtain the student's final score [16], as follows.

$$\text{Final score} = \frac{\text{Total of obtained score}}{\text{Maximum score}} \times 100 \qquad (6)$$

The final score obtained by students is used to know product effectiveness through the range criteria as presented in Table 4 and Table 5.

Table 4 Criteria of Student's Answer

Score	Criteria
86-100	Very good
76-85	Good
66-75	Moderate
55-65	Poorly
≤ 54	Very poorly

Source: Widoyoko [18]

Table 5 Criteria of Product's Effectivity

Percentage (%)	Criteria of Effectivity
81-100	Very effective
61-80	Effective
41-60	Effective enough
21-40	Uneffective
0-20	Very uneffective

Source: Riduwan [19]

Analysis Student's Responses Through Questionnaire

Student's response data was obtained from a questionnaire that was distributed to students after the process learning of using the interactive LKPD was completed. The percentage of student's responses via questionnaires can be calculated using formula 7 as follows.

$$\text{Percentage} = \frac{\text{Total of obtained score}}{\text{Maximum score}} \times 100\% \qquad (7)$$

The calculation results are then converted and adjusted to Table 6.

Table 6 Criteria of Student's Responses and Practicality

Percentage (%)	Criteria of Student's Responses	Criteria of Practicality
81-100	Very good	Very practical
61-80	Good	Practical
41-60	Moderate	Practical enough
21-40	Poorly	unpractical
0-20	Very poorly	Very unpractical

Source: Riduwan [19] dan Riduwan [20]

RESULTS AND DISCUSSION

This study is research that produces a product in the form of an AR-assisted interactive worksheet on the topic of molecular shapes for class X SMA which meets the criteria of being valid, practical, and effective. This research refers to the 4D development model [11] which has been modified into 3D, namely Define, Design and Develop

Result of the Define Stage

The define stage consists of three main steps, namely analysis of teaching material needs, student's analysis, and concepts analysis.

Result of Analysis of Teaching Material Needs

This stage was carried out through interviews with two chemistry teachers at class X SMAN 1 Kalasan and was based on the results of student surveys via Google Forms. Based on interviews with the teachers they provided material with simple LKPD which he had simply developed himself and class X chemistry printed books, modules and LKPD which had been provided by the Ministry of Education and Culture. Apart from that, they only used media such as Power Point (PPT)

which they developed themselves and videos from YouTube as assistance in supporting chemistry learning. They did not know about interactive LKPD and AR. Besides that, they had never even known about, developed or used AR-assisted teaching materials in chemistry learning. Other information found based on survey results among students is that the majority of students do not know about interactive LKPD and AR.

Result of Students Analysis

The results of the students analysis stage were obtained through a survey questionnaire filled in by all students of class X at SMAN 1 Kalasan. Apart from surveys, data was also obtained from the average daily test scores on the topic of molecular shape. This data was obtained from the results of an interview with the class survey of students found that 79.3% with a total of 73 students stated that the topic was difficult and 20.7% with a total of 19 students could follow it well.

This data showed that the majority of students find it difficult on the topic. This is supported by the results of interviews with teachers, that the topic is indeed one of the topics that is more difficult for students to understand when compared to other chemistry topics. In addition, the survey results also showed that the topic is the most difficult topic during class X chemistry learning based on the highest percentage of 75% with a total of 69 students.

Result of Concepts Analysis

The concept analysis stage aims to serve as a guide in identifying core concepts in developing products in the form of LKPD based on the results of the needs analysis. The chemistry topic chosen in developing AR-assisted interactive worksheet products is the topic of molecular shapes. Based on the results of student analysis through surveys and interviews with class X chemistry teachers, the topic is the most difficult topic during class

Basic Competence (BC) used in this research is BC 3.6, which applies valence shell electron pair theory (VSPER) and electron domain theory in determining molecular shape. The GPA described from BC 3.6 consists of two GPAs, namely GPA 3.6.1 and GPA 3.6.2. The learning objectives developed based on each GPA consist of one, namely GPA 3.6.1 with learning objectives at point 3.6.1.1. Meanwhile, GPA 3.6.2. with the aim of 3.6.2.1.

Result of Design Stage

The design stage consists of two steps, namely selecting the AR-assisted interactive LKPD format and product design. The choice of LKPD product preparation format refers to [21]. Product design consists of several steps using several applications so that the LKPD product developed is attractive and is expected to help students.

Design of 2D Object and Animation Video using Canva

In designing this object, the main application used as a designer and producer of the final object in the form of a barcode is Assemblr Studio. Assemblr Studio is a web-based (AR) creator for creating, viewing, and sharing AR creations in the browser without needing to download any applications [22]. However, the Assemblr Studio application has limited features, so additional 2D objects from other applications are needed. One of them is using the Canva application.

At this stage, Canva is used as a designer of 2D objects and animated videos. At this stage, Canva is used as a designer of 2D objects and animated videos. Canva has limitations, namely that it cannot create 3D effects or models, so its use is limited to 2D and video. The 2D object designed is a card explaining the color of the atomic balls of each compound. The object is then input into Assemblr Studio as a complement to the final object in the barcode.

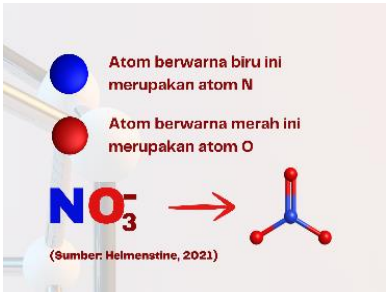

Figure 1 One of Result of Design of NO_3^- using Canva

Moreover, Canva is also used to design animated videos which represent the movement of the molecular shape of a compound so that

the concept of the topic is more easily conveyed. The animated video object is uploaded to YouTube and then the link from YouTube is inserted into Assemblr Studio as a complementary object.

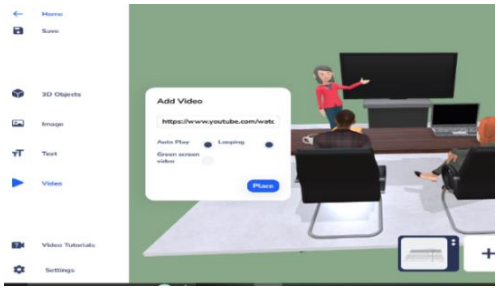

Figure 2 Uploading Link YouTube to Assemblr Studio

Design 3D Object Using Blender

Apart from 2D objects and animated videos, 3D objects are also needed to create interesting content. The 3D objects provided in Assemblr Studio are still limited, so researchers design shapes that are not available in Assemblr Studio using the Blender application. The Blender application is a free tool used to create 3D visualizations using modeling, motion tracking, and texturing features [23]. The use of this application is because Blender has the advantage of being free and open source [24].

The objects designed in the Blender application are 42 atoms that make up each compound in the form of a molecule and 1 stick as a bond for the atoms for each compound. The length of the ties made is 30 mm with a diameter of 2.8 mm. This is so that the bond stick can be seen clearly. List of atomic sizes refers to ChemLibre [25].

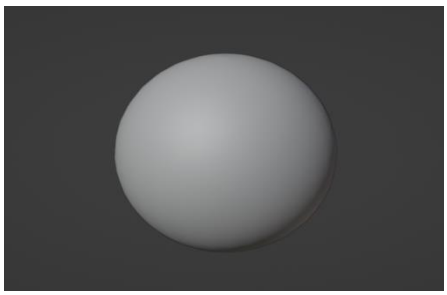

Figure 3 Result of Design 3D Object Using Blender

Objects that have been designed in the Blender application are also input into Assemblr Studio. Uploading 3D objects from outside the application must be in fbx format. Settings for uploading objects into the application include three parts, namely object settings, thumbnail settings, and preview settings. The coloring of atomic objects from the Blender application is done in Assemblr Studio when you want to insert the object into the scene. The object will then be arranged or designed in Assemblr Studio and will then become a complementary part of the final product in the form of a barcode that is input into the product.

Design and Arrange Layout of 3D Objects Using Assemblr Studio

The design made in Assemblr Studio is the arrangement of 14 molecular shapes with 2 types of visualization models, namely molecular shapes in 3D dimensional sculptures and molecular shapes in video animation. The results of preparing the final object are in the form of molecules which will become a complementary part of the final product in the form of a barcode which is input into the interactive LKPD product. At this stage, coloring is also carried out on the atoms that make up the molecular form of the compound. Atomic coloring in Assemblr Studio follows international color rules according to Helmenstine [26].

The results of the design and preparation of the final object in Assemblr Edu are published in the form of a barcode which will be scanned by students using one of the AR applications, namely Assemblr Edu. Barcode Assemblr Edu which is a complement to interactive LKPD products. The following is an example of Assemblr Edu barcode results in an interactive LKPD product.

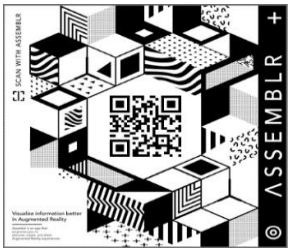

Figure 4 One of Barcode of Molecular Shape in Product

Design Product Using Canva and Liveworksheets

Apart from being an object designer, Canva is also used to design interactive LKPD products to make them more attractive. In the design stage, Canva provides various content

illustrations in template form so that they can be used immediately. Apart from that, there are also font types and various other features to support creativity in creating product designs [27]. Designing interactive LKPD products in Canva starts from the front cover to the references by utilizing various template features, images that are appropriate to the topic of molecular shapes. LKPD product components that have been designed are saved in PDF form.

Figure 5 Result of Design Product in Canva

The final product of AR-assisted interactive LKPD will be accessed by students via the Liveworksheets link inputted into Bit.ly. AR-assisted interactive worksheet products on the topic can be accessed via the link: https://bit.ly/LKPDInteraktif-BentukMolekul

Analysis of Develop Stage

Results at the development stage were obtained from two steps, namely validation product and instruments and limited trials.

Result of Product Validation

The results of product validation in the form of AR-assisted interactive LKPD on the topic—were validated by two chemistry education lecturers and chemistry teacher. The product assessment component consists of four aspects described in 21 statements. These aspects are aspects of appropriateness of content (5 statements), grammar (2 statements), presentation and appearance of the product (9 statements), and appropriateness of graphics (6 statements). Validation results can be seen in Table 7.

Table 7 Result of Product Validation

No.	Aspects	Average (%)	Criteria of Eligibility	Criteria of Validity
1	Content	92	Very eligible	Very valid
2	Grammar	83	Very eligible	Very valid
3	Display	85	Very eligible	Very valid
4	Graphics	86	Very eligible	Very valid
Average		87	Very eligible	Very valid

From Table 7, it can be seen that the content feasibility aspect has an average validity of 92% with very feasible criteria in the very valid criteria. The grammar aspect has an average validity of 83% with very appropriate criteria in the very valid criteria, then the presentation and appearance aspect of the product has an average validity of 85% with very appropriate criteria in the very valid category. Meanwhile, the graphic feasibility aspect has an average validity of 86% with very feasible criteria in the very valid category. The average results of the product validation assessment show very feasible criteria with a very valid category of 87% in all aspects. According to Arikunto [14], a feasibility score with a range of ~~(~~76-100%~~)~~ is included in the very feasible criteria. Meanwhile, according to Arikunto [13], the validity score in the range of ~~(~~76-100%~~)~~ is included in the very valid category. Products in the form of interactive LKPD can be said to have a good level of validity if the minimum level of validity achieved in the criteria is high [28].

Result of Validation of Questions Item

The results of the validation analysis of the questions in the product were carried out on the six questions. The components analyzed in validating the questions in the product consist of three aspects which are described in 8 statements. These aspects are the material aspects of the question (3 statements), construction (3 statements), and language (2 statements). Analysis of question items was carried out based on Aiken's validity coefficient (Aiken's V).

Almost all of the questions are at a very high average criterion. According to Retnawati [15], a validity score with a V value > 0.80 is included in the very valid criteria. In question number 1, it is known that an average validity coefficient of 1.00 was obtained. This shows that question item number 1 has very valid criteria and can be used. In question item number 2, an average validity coefficient of 0.94 was obtained, which shows that the question item has very valid criteria so it can be used. Question item number 3 has an average validity of 0.88, which means it is very valid, so question item number 3 can be used well.

Furthermore, in question number 4, an average validity coefficient of 0.94 was obtained with very valid criteria. This means that the questions can be used in the product. In question number 5, it has an average validity of 0.80 with medium criteria and can also be used. This is because the questions have unclear sentences. However, the questions can still be used with improvements to the questions from the validator. The last question item, question number 6, has an average validity coefficient of 0.90, which shows that the question item has very valid criteria so it can be used.

Result of Validation of Questionnaire Sheet

Validation of the student response questionnaire to the product consists of three aspects described in 9 statements. These-aspects are aspects of content and purpose (3 statements), construction (4 statements), and language (2 statements). The results of the product response questionnaire validation can be seen in Table 8.

Table 8 Result of Validation of Questionnaire Sheet

No.	Aspects	Average (%)	Criteria
1	Content	100	Very valid
2	Construction	97	Very valid
3	Grammar	79	Valid
Average		92	Very valid

Based on Table 8, it can be seen that the content and objective aspects have an average percentage of 100% with very valid criteria. The construction aspect has an average percentage of 97% with very valid criteria. Then the language aspect has an average percentage of 79% with valid criteria. The overall average of student response questionnaires to products has a percentage of 92%. According to Akbar [17], the validity score in the range of (76-100%) is included in very valid criteria. This shows that the questionnaire on student responses to products has very valid criteria and can be used in this research

Result of Trial

This stage is carried out after the validation and revision process of the product and research instruments has been carried out. The trial was carried out in one meeting with a sample of 10 students of class X MIPA SMAN 1 Kalasan. The sample selection was carried out by teachers based on different cognitive levels, namely high, medium and low. This aims to determine the readability of the product for various students' abilities, so it is hoped that this product can be used and help students' understanding regardless of the students' cognitive level.

In general, product can be used well by students. Students also observe every part of the interactive LKPD, starting from the cover page to other parts. In the instructions for use section, students read carefully each point of the instructions then continue to read the BC, GPA, and learning objectives in the product. Students read short material on the product and scan barcodes for examples of $BeCl_2$ and SF_4 compound questions before working on interactive questions. When working on AR-assisted interactive questions, students feel enthusiastic about working because of the material presented on the Assemblr Edu barcode. In the work process, students work by reading the material in the barcode and then filling in the answers in each answer box provided.

In Assemblr Edu barcodes, there are various features such as 2D, 3D, and animated videos. This increases students' interest in the work and makes it easier for students to understand the concept of molecular shape. This is in line with Derlina & Afrianti [29], that the application of learning assisted by visual media in the form of videos makes learning interesting, helps students understand abstract concepts. Besides that, the presence of 2D and 3D objects in product can make learning even

more interesting. The aim of using AR in this interactive LKPD product is to be able to visualize abstract molecular shapes as if they were real and can be displayed around us [30]. Based on this, the aim of using AR in LKPD products was successful. The use of AR is very suitable to support digital-based learning and obtain positive responses from students [31].

Students have an average score of 99. In Widoyoko [32], scores in the 86-100 range are in the very good category. This shows that the students' answers fall into the high category. So, it can be concluded that the product being developed falls under the criteria of being very effective [19]. The average result of student response analysis was 93% with very good questionnaire criteria [20]. The average percentage of student responses per aspect item in the questionnaire was 92.81%. Apart from assessing through several statements in the questionnaire, students also provide positive comments on the product. Students provided comments with a percentage of 70% stating that the product was interesting and easy to understand due to the variety of animated videos and 3D media. Based on the percentage of student responses, the product can be said to be very practical [19]. Product practicality is the level of ease of use of AR-assisted interactive LKPD [17].

CONCLUSION

Based on the results of the research and discussion that have been described, it can be concluded that:

1. The product in the form of an AR-assisted interactive worksheet on the topic of molecular shapes that has been developed meets the eligibility criteria with average validity of 87% with very feasible and very valid criteria, the average effectiveness obtained from the average student answer result being 99 with the average percentage of completeness in working on interactive questions being 97%, and very practical criteria obtained from the average student response to the product of 93%.
2. Average percentage of student responses per aspect item in the questionnaire of 92.81% and as many as 70% of students provided comments stating that the product was interesting and easy to understand.

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