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Development of an Augmented Reality-Based Practicum E-Module Integrated with Local Wisdom of Salak Fruit

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Abstract

The integration of augmented reality (AR) technology into education has gained attention as an innovative tool to enhance students' learning experiences, particularly for abstract concepts such as chemical bonding. E-modules that incorporate AR can provide three-dimensional visualizations, making complex topics more accessible and engaging. This study aims to develop and validate practical e-modules using AR technology to enhance students' spatial intelligence while incorporating local wisdom from Padangsidimpuan. The research follows a Research and Development (R&D) approach using the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model and a pretest-posttest control group design. Data were collected from three high schools in Padangsidimpuan using simple random sampling. Instruments included validation sheets (for material, media, and language), observation, user response questionnaires, and pretest-posttest tests to assess students' spatial intelligence. The e-module achieved high validation scores: 0.9 (material), 0.8 (media), and 0.9 (language). Student response rates were 80% (feasibility), 85% (AR usage), and 83.2% (language). Teachers provided an average response score of 88.6, indicating high practicality. The spatial intelligence assessment across the three schools yielded an average score of 0.85 in the high category. The AR-based e-modules effectively improve students' spatial intelligence by visualizing abstract chemical bonding concepts in 3D. This innovation contributes to enhancing chemistry education and preserving local wisdom in Padangsidimpuan, offering a model for future educational advancements.

Keywords : augmented reality, chemical bonds, e-module, local wisdom

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1. Introduction

This time, the proposer recognized the shift in learning direction that in the era of society 5.0, technological trends were becoming part of the virtual revolution. Previous research by Pohan & Lubis (2019) had created a practicum guide that included the concept of chemoentrepreneurship, which is capable of producing products of economic value. Researchers may now perform high-level and macro experiments thanks to the creation and development of virtual laboratories, which also serves as a hub for community and knowledge needs (Iakovides et al., 2022); (Almaatouq et al., 2021). Experiments can assist students grasp chemistry topics and translate them into practical knowledge once they have learned the theory. But given safety issues, a shortage of instructional time, and a paucity of lab supplies, some educators frequently decide to. This has implications for low motivation to experiment in the laboratory and for students' spatial intelligence (Tarng et al., 2021). The concept of chemical bonds is one of the fundamental concepts in chemistry that is difficult to understand because the study of atoms combining to form compounds is relatively abstract and difficult to understand visually. Students' weak spatial intelligence is one of the causes of the difficulty in visualising the shape of chemical bonds, which requires the ability to understand structural formulae and translate them into three dimensions (3D) (Isaloka & Dwiningsih, 2020).

Despite having typical levels of spatial intelligence, students must work harder to understand 3D concepts than other concepts, according to earlier research (Yip et al., 2019). Because visual learning aids offer a variety of shapes, structural plans, maps, tables, charts, graphs, and diagrams, students prefer them (Qodirovich et al., 2021). To comprehend chemical concepts and to generate, preserve, and work with abstract visual pictures, students must be able to combine conceptual knowledge with spatial intelligence. The findings of observations were collected from three high schools in Padangsidimpuan through interviews with three chemistry professors sparked the urgency of this study. Because students struggled to determine the chemical bonding material, it was determined that the low daily test scores were still below 50%. Similarly, the process of forming covalent, ionic and metallic bonds was difficult to identify. In fact, understanding the types and identification of chemical bonds is a basic knowledge that students need to have before doing a chemical bonding lab. On the other hand, teachers have not yet fully innovated in designing interactive lab guides, even though the current independent curriculum emphasises 21st century skills, which are collaboration, creativity and critical thinking. There are three levels of chemical representation that can be seen in Figure 1.

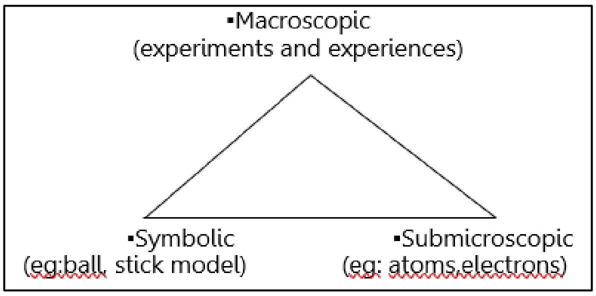

Figure 1. Three Level of Chemical Representation (Isnaini, 2018).

One of the development of teaching materials that are relevant to digital development is practicum e-modules based on Augmented Reality (AR) (Serevina et al., 2018). AR is a technology that combines the real world with virtual objects. This technology can be used to create a more interesting and interactive learning experience (Waldman, 2016); (Allo & Suhendra, 2022). The virtual objects then appear live and real side by side in the same space (3D). Salak fruit, one of the local fruits that is unique and rich in nutrients, is one of the local wisdom products in Padangsidimpuan that contains chemical compounds. This research was limited to five compounds such as water, glucose, alanine, ascorbic acid and NaCl. Using these chemical compounds, several types of chemical bonds can be interpreted. Although they do not cover all types of chemical bonds, it is hoped that students will be more interested in doing practical work with objects they recognise. Students find it difficult to imagine the structure of the molecular shape in real terms when presented in 2D (Saraswati et al., 2017). Therefore, 3D visualisation of the molecular shape presented through AR technology has the potential to improve students' visual representation skills, motivation and learning outcomes (Rahmawati et al., 2021); (Wahyudi & Arwansyah, 2019). Learning modules can be used to optimise the understanding of chemical concepts. This is because modules are structured materials that are systematically designed so that students can learn according to their own abilities and are not dependent on the teacher (Yuni & Afriadi, 2020). Moreover, if the learning module is integrated with AR technology, it will make it easier for students to understand the material presented (Kusdiyanti et al., 2020). The development of an AR-based practical e-module integrated with the local wisdom of Salak fruit has never been researched before. Therefore, in this research, we develop an AR-based practical e-module integrated with the local wisdom of Salak fruit. This e-module is expected to contribute to innovation in chemistry learning and be able to preserve the local wisdom of the town of Padangsidimpuan.

2. Research Method

This research was conducted in three public high schools in Padangsidimpuan. The subjects in this research consisted of three classes of students majoring in sciences and mathematics. The research was conducted with the help of three chemistry teachers from each school, and four lecturers as media, material and language expert validators. The method used was part of research and development (R&D) method, to develop and test products that will later be developed in education. The ADDIE development model is based on an effective and efficient systems approach and an interactive process between students, teachers and the environment. In development research, the ADDIE model is used as a framework for the design and development of learning programmes, which are the research objectives. The model has five main stages: Analysis, Design, Development, Implementation and Evaluation (ADDIE). The ADDIE model cycle can be seen in Figure 2.

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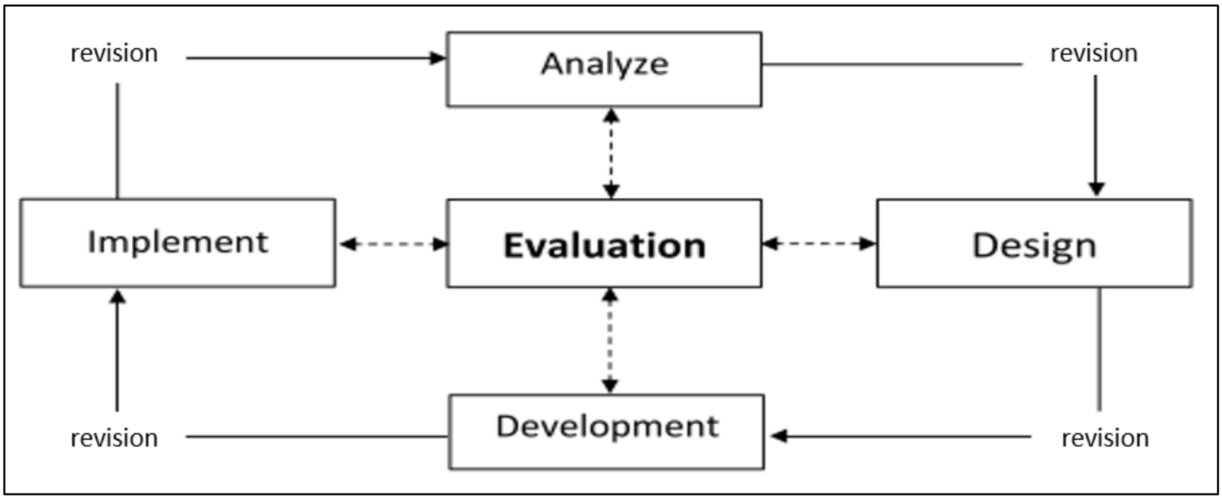

Figure 2. **ADDIE Model Cycle (Branch, 2009)**

The following table shows the steps for developing the that will be implemented in this research. The steps of e-module can be seen in Table 1.

Table 1. Steps of E-Module

Design ADDIE	Method
Analyze Objective: identify student needs related to spatial abilities, problems, and learning objectives.	Observation of 3 schools. Interviews: gain in-depth insight from students and teachers regarding challenges and needs related to spatial abilities. Document Study: Reviewing literature, curriculum, and chemical bond learning materials. Pretest: Conduct an initial test to measure students' spatial intelligence
Design	Brainstorming: Generate creative ideas for e-module design.

Design ADDIE	Method
Objective: Designing the e-module framework	Storyboarding: Creating an initial sketch or blueprint of the e-module. Prototyping: Creating an initial version of the e-module for initial testing. Solicit input from education and technology experts regarding the proposed design.
Development Objective: Develop the content and technology required for an e-module that focuses on spatial abilities	Content Development: Writing material, creating graphics, animations and AR elements, validation by expert validator. Programming: Coding AR applications or platforms that support e-modules. Objective: Develop the content and technology required for an e-module that focuses on spatial abilities
Implementation Objective: Implement e-modules in a real learning environment.	Teacher Training: Provide training to teachers on how to use AR-based e-modules. Field Trial: Implementing the e-module in a class or small group of students to test its effectiveness and administering a posttest to measure students' spatial intelligence. Observation: Observe the use of e-modules in a real environment to identify problems and provide feedback.
Evaluation Objective: To assess the effectiveness of e-modules on students' spatial abilities	Formative Evaluation: Gathering feedback during the development and implementation process for immediate improvements, especially regarding. aspects of spatial intelligence. Summative Evaluation: Assess the final results after full implementation to see whether the goal of improving spatial intelligence was achieved. Questionnaire: Collect data from students and teachers regarding their experiences using e-modules. Data Analysis: Analyze qualitative and quantitative data to evaluate the impact of e-modules on students' spatial intelligence, including comparisons test results before and after using the e-module.

To examine the validity of the e-module, it was obtained from the results of the validity of the Aiken's V technique in the form of content/material, media, language and IT. Aiken's V formula with the following formula with the V coefficient value located between 0 and 1.

$$V = \sum S / [n (c - 1)]$$

S = r – lo
V = content validity index
r = figures given by the appraiser
n = number of raters/validators
c = highest rating number
lo = lowest assessment

The Aiken's V validity data obtained will be categorized into indexes in the following Table 2.

Table 2. Category of Validity

Category	Score
Low Validity	$V < 0{,}4$
Medium Validity	$0{,}4 \leq V < 0{,}8$
High Validity	$V \geq 0{,}8$

For learning outcome tests, pre- and post-tests of spatial ability, the questions used must be tested for their feasibility through validity tests, reliability, level of difficulty and discriminative power using the SPSS programme, then the data from the spatial ability test are calculated using the N-gain calculation using the formula:

$$\text{N-Gain} = \frac{postest - pretest\ score}{high\ score - pretest\ score} \text{ x } 100\%$$

Once the value has been obtained by means of the formula above, the value is then categorised on the basis of the criteria in the Table 3.

Table 3. Criteria of N-Gain

N-Gain	Criteria
>0,7	High
0,3> N-Gain >0,7	Medium
>0,3	Low

(Meltzer, 2002)

3. Result and Discussion

3.1. Analyze

A problem and needs analysis are carried out before the development phase. The results of the interviews with the teachers, the incomplete laboratory equipment and the use of the pre-test instrument showed that the value of the students' answers on chemical bonds was very low. Practical work is necessary for students to understand the theory of chemical bonds. The aim of this analysis process is to produce a practical e-module. Provide appropriate interventions to address learning gaps based on problems and needs (Asmar & Suryadarma, 2021).

3.2. Design

Next stage the storyboard design was used as a reference in developing a practicum e-module based on augmented reality integrated with salak fruit. Some of the software used in designing this e-module is the BlipAR, Assemblr.edu and Canva applications, while the tools used are laptops, webcams and smartphone.

Designing learning content starts from formulating learning objectives according to the chemistry syllabus then compiling the structure of chemical bonding material. Then design practical steps to integrate with AR technology. Furthermore, the pretest and posttest questions are arranged based on spatial indicators. The storyboard of AR-based practicum can be seen in Figure 3.

Figure 3. Storyboard of AR-Based Practicum E-Module

In Figure 3, a storyboard that provides a visual overview of how the e-module will be structured and how AR will be integrated to improve students' spatial intelligence in the context of learning chemical bonds using snake fruit as an applicable example, is presented.

3.3. Development

The practicum e-module designed with the Canva application is in PDF format with a file size of 8.2 MB, so the practicum e-module can be seen in Figure 4.

Figure 4. Display of AR-Based Practicum E-Module

Next, the validation stage by experts which includes material validation, media validation and language validation. The average score of material expert validation results can be seen in Table 4 .

Table 4. Validation Result by Material Expert

No	Aspect	Material Expert 1	Material Expert 2	S1	S2	∑S	V	Criteria
1	The material presented is in accordance with the learning objectives	5	4	4	3	7	0.9	Valid
2	The concept of chemical bonding is presented accurately	5	5	4	4	8	1	Valid
3	The integration of salak fruit is relevant to chemical bonding material	5	5	4	4	8	1	Valid
4	The Lewis structure picture of chemical compounds in salak fruit is presented in full	5	5	4	4	8	1	Valid
5	The use of salak fruit as a local context was considered effective and interesting in the experiment	5	5	4	4	8	1	Valid
6	Animation visualization of 3D molecular shapes experiments according to practical material	5	4	4	3	7	0.9	Valid
7	Experimental material is supported by images, photos, animations and practice	5	5	4	4	8	1	Valid
8	Practical instructions are clear and easy to understand	5	5	4	4	8	1	Valid
9	The use of AR in experiments supports understanding of the concept of chemical bonding	5	4	4	3	7	0.9	Valid
10	The depth of the experimental material is appropriate to the student's cognitive level	4	4	3	3	6	0.8	Valid
11	Experiments increase students' understanding of chemical bonds	5	5	4	4	8	1	Valid
12	The experiment supports increasing students' spatial intelligence	5	5	4	4	8	1	Valid
V Value					**0.9**			**Valid**

The second validation was the validation of media experts, by two lecturers from different universities. The purpose of media validation is to obtain data on the validity of prototypes that have been tested from the point of view of the graphic suitability of the e-module, the design of the content and the design of the augmented reality application. The results of the media validation can be seen in the Table 5.

Table 5. Validation Results by Media Experts

No	Aspect	Material Expert		S1	S2	∑S	V	Criteria
		1	2					
1	Graphic Eligibility	4.5	4.25	3.5	3.25	5.75	0.7	Valid
2	Feasibility of AR practicum guide e-module content design	4	4.6	3	3.6	6.6	0.8	Valid
3	Use of Augmented Reality Technology	3.8	4.6	2.8	3.6	6.4	0.8	Valid
	Total V						**0.8**	**Valid**

From Table 5, the value for graphic feasibility aspect data is 0.7, feasibility of AR practice guide e-module content. The final validation was validating the appropriateness aspect of language design is 0.8, and use of Augmented Reality technology of 0.8 very valid. Based on the results of the media aspect, the validator suggested to design the cover colour a little brighter to make it more attractive, and to enlarge the chemistry logo with an attractive appearance, which is expected to motivate students to learn more (Harackiewicz et al., 2016). The above values are valid criteria from two language expert lecturers. The validation result of linguist can be seen in Table 6.

Table 6. Validation Result of Linguist

No	Aspect	Linguist		S1	S2	∑S	V	Criteria
		1	2					
1	The sentences used in the e-module are effective.	5	4	4	3	7	0.9	Valid
2	Terms used in standard e-modules.	5	4	4	3	7	0.9	Valid
3	The language used in the E-Module can increase motivation learners.	4	4	3	3	6	0.8	Valid
4	The language used is appropriate to the student's level of cognitive development	4	3	3	2	5	0.6	Valid
5	The use of language is communicative and easy to understand	5	4	4	3	7	0.9	Valid
6	The term chemical bond is used precisely and consistently	5	4	4	3	7	0.9	Valid
7	The sentence structure used is effective and unambiguous	5	4	4	3	7	0.9	Valid
8	The use of symbols, terms and icons is consistent throughout the e-module	5	4	4	3	7	0.9	Valid
9	The use of analogies and similes in explaining concepts is precise and helps understanding	5	4	4	3	7	0.9	Valid
10	Explanation of the concept of chemical bonds using clear and easy to understand language	5	4	4	3	7	0.9	Valid
11	Instructions for using AR are explained in easy-to-follow language	5	4	4	3	7	0.9	Valid
12	The context integration of salak fruit is explained in relevant and interesting language	5	4	4	3	7	0.9	Valid
	V Value				**0.9**			**Valid**

Table 6 shows that the overall validity of the language presented in the e-module is very high. This can be explained by the fact that the language in the e-module is presented in a simple and clear way so that it can help the reader to understand the intention and meaning of what is being studied. In terms of clarity of language, several improvements were found in terms of writing errors such as the use of capital letters, standard terms and punctuation that need to be considered. The score percentages of each media, material and language expert are 0.9, 0.8 and 0.9, giving an overall average of 0.86, which means that three validation results are very valid and can be used without correction (Fitri et al., 2023)

3.4. Implementation

Meanwhile, using the augmented reality application is easy to access by simply clicking on the marker provided in the practical e-module, then students can see the 3D display in the real world or on Android, as seen in Figure 5.

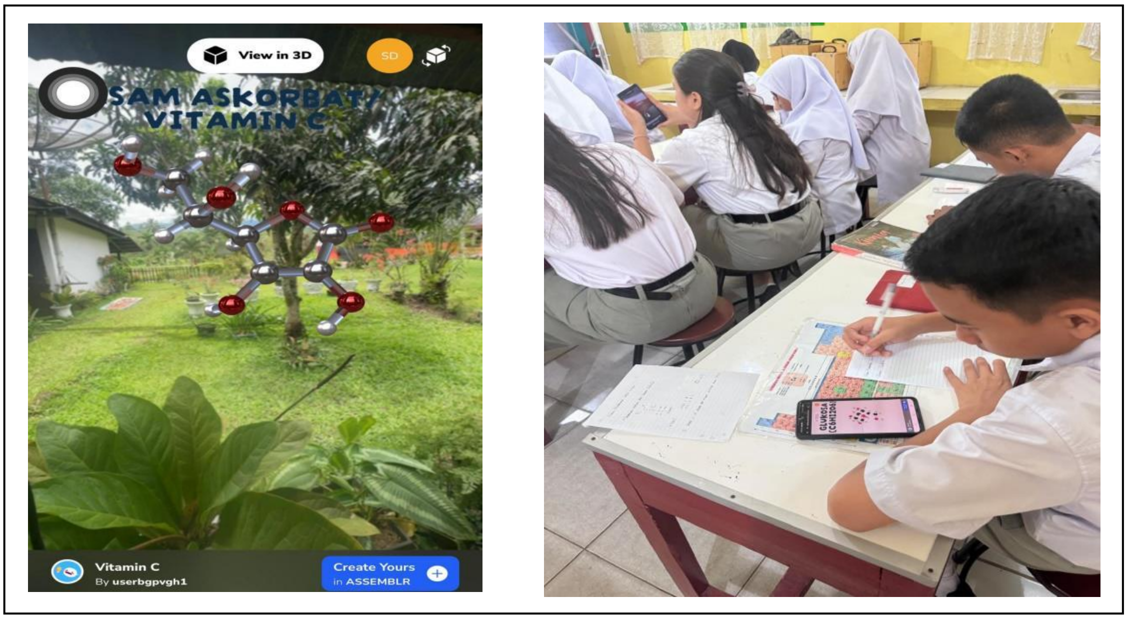

Figure 5. 3D Augmented Reality View of Chemical Compounds in Salak Fruit

Once the object is presented in 3D form, the visualisation projected by the assembler application provides the user with a real visual stimulation experience in the form of an arrangement of atoms in a molecular geometry. 3D object visualisation makes it easier to illustrate phenomena that are difficult to understand (Mansor et al., 2020). A study conducted by (Raja & Nagasubramani, 2018) on the development of technology in learning, such as 3D visualisation devices, is an excellent resource for teachers to help students easily understand concepts. Students are able to use augmented reality based modules because there are clear instructions on how to use them, visualisations that can be viewed from different angles through the use of augmented reality. Reality can be seen from different angles. Students are also more interested in learning uses augmented reality technology and modules that are designed with attractive and bright colours. The module is designed with attractive and bright colours (Fadhila et al., 2023). Therefore, the application of AR technology in practical learning will focus on visualisation and interaction between users and objects in real environment applications, so that students can easily imagine and visualise the concept of abstract molecular shapes, thus improving students' spatial intelligence.

3.5. Evaluation

From the results of the validation of the material aspects using Aiken's V technique, it shows a high valid category, but the suggestions for improvement from the validator will be considered for revision if necessary. The practice questions are quite good, but according to the validator, questions four and five should be deleted because they do not match the cognitive level of the students. The other practice questions are good and can develop students' spatial skills, as shown in Figure 6.

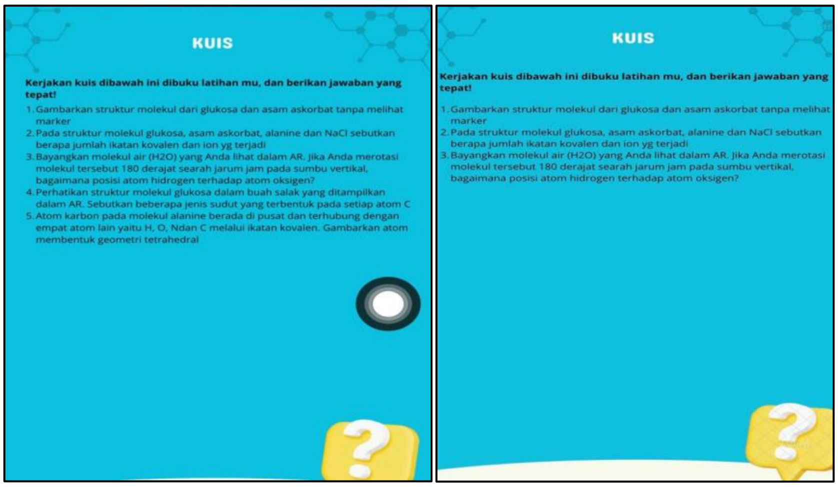

Figure 6. Quiz Display Before and After Revision

From the graph, it can be seen that the results of the tabulation of the data from the students' responses to the questionnaire on the e-module of the placement are 80% for the appearance aspect, 85% for the AR usage aspect and 82% for the language aspect, so the average percentage of all aspects is 82.3% with a good response category. The diagram of student assesment result on e-module can be seen in Figure 7.

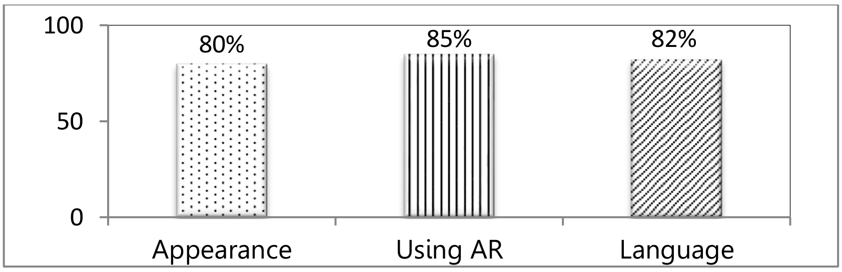

Figure 7. Diagram of Student Assesment Result on E-Module

Table 8 shows that the development of the practical e-module was considered practical by three chemistry teachers, consisting of seven aspects, design aspect 93.3%, material aspect 91.1%, practical aspects 89.1%, language ability 86.9%; use of AR 78.3%, integrated salak fruit 93.3% and spatial intelligence 88.3%, the average practicality is 88.6%. To find out the students' responses to the aspects of usability, appearance, benefits and satisfaction in using e-modules and applications, a practical test was used, in all aspects the average result was 88.6%. This result shows a very positive response that the practical e-module can visualise chemical bonds so that students can better understand the form of chemical bonds from the object of salak fruit content. This finding is consistent with the results of previous studies, according to (Krüger et al., 2019), some of the characteristics of AR are its ability to provide 3D virtual object visualisation in a real-world environment, and it can provide users with an interactive experience of interacting with virtual objects.

In order to assess the spatial intelligence of the students, they use an e-module for practical training by calculating the students' pre-test and post-test scores. After receiving the data from the three schools, the average is tabulated using the N-Gain formula, which is then interpreted as high, medium or low spatial gain. The following is a table of N-Gain values from the three school. The practicality test results by chemistry teachers can be seen in Table 8.

Table 8. Practicality Test Results by Chemistry Teachers (Percent)

Aspect	Chemistry Teachers			Average	Category
	1	2	3		
Cover Design	95	90	95	93.3	Practical
Material Aspects	93.3	93.3	86.6	91.1	Practical
Practical Aspects	90	87.5	90	89.1	Practical
Language suitability	80	87.5	93.3	86.9	Practical
AR Use	55	90	90	78.3	Practical
Integration of salak fruit	90	90	100	93.3	Practical
Spatial intelligence	90	90	85	88.3	Practical

The table above shows the results of the students' spatial ability tests with an average of 0.8, 0.9, and 0.85 with a high interpretation, the average N-gain for the whole school is 0.85, which is classified as high. N-Gain pretest-postest can be seen in Table 9.

Table 9. N-Gain Pretest-Postest

School	Average N-Gain	Interpretation
SMA 1	0.8	High
SMA 4	0.9	High
SMA 6	0.85	High
Average for all schools	**0.85**	**High**

4. Conclusion

Based on the results of the research conducted, it is concluded that the Augmented Reality-based e-module product Integrated Salak Fruit is practical and valid. With an average validation score of 0.9 from material experts, 0.8 from media experts and 0.9 from language experts, everything is declared valid. Similarly, positive responses were also obtained from students, which are 80% for the feasibility aspect, 85% for the AR use aspect and 83.2% for the language aspect. Meanwhile, the response from the chemistry teachers was an average of 88.6 in the practical category. And the last one is an assessment of students' spatial intelligence, the average score obtained for the three schools is 0.85, which is considered high.

The results of this research prove that AR technology integrated with local wisdom of snake fruit in practical chemistry can create a more effective and meaningful learning experience, while supporting the development of students' spatial intelligence.

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