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Development of Interactive E-Modules as a Learning Media to Train Visual-Spatial Intelligence on Intermolecular Force Materials

Aulia Pratamadita, Kusumawati Dwiningsih*
Chemistry Education Study Program, FMIPA, Universitas Negeri Surabaya
***Corresponding Author. Email: kusumawatidwiningsih@unesa.ac.id

Abstract: This research aims to determine the feasibility of the interactive e-module from its validity, effectiveness, and practicality as a learning media for high school students to train visual-spatial intelligence on intermolecular forces materials. The type of this research is Research and Development (R&D) with the ADDIE development model. There are five (5) stages at the ADDIE model, namely: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation. The instruments used in the interactive e-module validation process were content and construct validation sheets, pretest and posttest sheets for effectiveness, and student response questionnaires for its practicality. This researchs' data were analyzed descriptively quantitatively. The results of the interactive e-module validation obtained a percentage of 90.0% for content validation and a percentage of 90.5% for construct validation, both of which belonged to the very valid category. The effectiveness of the interactive e-module also met the classical completeness criteria, which is 80.0% in the intermolecular force material and 85.0% in the visual-spatial. The T-test results also showed a significant difference between the average pretest and posttest indicated by the sig. 2-tailed value of $0.00 < 0.05$ both in terms of intermolecular forces and visual-spatial. In addition, interactive e-modules were also said to be practical to use based on student responses which showed a score of 100% on the content aspect, 99.2% on the linguistic aspect, 97.1% on the usability aspect, and 100% on the presentation aspect. All of them were in the "Very good" category. From these results, it can be concluded that the interactive e-module to train students' visual-spatial intelligence on the material of intermolecular forces is feasible to use in terms of validity, effectiveness, and practicality.

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Introduction

Chemistry, a branch of science, involves many abstract concepts that cannot be directly actualized (Nuviandy & Dwiningsih, 2021). Because of this, most students consider chemistry to be a complex subject because of its abstractness, which must be represented in a scheme or model (Safitri & Dwiningsih, 2020). Previous studies stated that to understand the basic concepts of chemistry, students must understand at the macroscopic, sub-microscopic, and symbolic levels. The macroscopic level is a representation of form at the level of observable fact phenomena. The submicroscopic level is the level of representation based on observations that require some theories to explain the molecular part using theoretical approaches, such as microscopic particles that cannot be seen directly. The symbolic level is a representation based on facts and transformed into something simple, such as the symbolic representation of atoms, molecules, and compounds in images, algorithms, and computer processing forms (Becker, Stanford, Towns, & Cole, 2015).

Intermolecular forces material, which is included in the sub-material of chemical bonds, is one of the chemical materials studied by students in the tenth grade. The subject of intermolecular forces studies the interactions between molecules and their influence on the physical properties, categorized into dipole-dipole forces, London forces, dipole-induced forces, and hydrogen bonds (Permendikbud, 2018). This material is difficult for students to understand because it includes abstract concepts, interactions between molecules cannot be observed directly. Previous research has shown that a lot of students still do not develop a coherent understanding of the intermolecular forces material. Students seem to fail to understand the causes of interactions that occur between molecules (Cooper, Williams, & Underwood, 2015). The results of the pre-research also stated that 90% of students said that intermolecular forces are a chemistry material that is considered difficult, among others. Because interactions between molecules cannot be observed directly, this material belongs to the sub-microscopic and symbolic level because their interactions will require a model to visualize them. To understand this material, students must have good representation skills because the ability to visualize molecular shapes in the learning process is needed to understand the interactions. It is also mentioned in research conducted by Becker, Noyes, & Cooper (2016) that spatial abilities such as representing images are essential to provide meaningful understanding for students.

Visual-spatial intelligence is a person’s ability to visualize and synthesize data into concepts in visuals and images. Visual-spatial intelligence measured the ability to imagine objects, create global shapes by finding the location of small components, or understand the differences and similarities between objects. Chemistry learning that combines the process of transforming sub-microscopic (visual) representations into verbal and symbolic or vice versa can help students get better concepts quickly (Tres & Brucki, 2014). Research conducted by Sunyono & Sudjarwo (2018) states that the understanding of most high school students is still at the macro level, and students still have difficulty interpreting a model. For this reason, students’ visual-spatial intelligence needs to be trained and improved to increase students’ ability to understand materials at the sub-microscopic and symbolic levels, such as intermolecular forces.

From direct observation, most of the teachers are only using Powerpoint as a learning media in class. Supported by the pre-research, 75% of students also stated that Powerpoint is often used as learning media in class. The ineffectiveness of long-distance learning applied due to the Covid-19 also with the difficulties in understanding sub-microscopic and symbolic level material because of limited learning media that is used make an interactive learning media is very much needed. It is important to find a solution to help students understand sub-microscopic and symbolic level material that requires complex spatial understanding (Saloka & Dwiningsih, 2020). One solution that can be expected to help students understand the subject matter well is to utilize online media or interactive multimedia-based media (Budiyono, 2020). This solution is in line with Tamami & Dwiningsih’s (2020) research, which states that interactive multimedia can significantly affect students’ visual-spatial intelligence. Ainyn & Dwiningsih’s (2020) also stated in the results of their research that interactive multimedia is able to provide visual intelligence stimulation that can affect students' understanding of concepts.

An intermediary that can facilitate the learning process to make teacher and student communication more effective is called learning media. Electronic modules or e-modules are digital learning media that are systematically arranged to be used independently by users. In this case, students will choose and determine the following steps or content according to their will (Agustina, Damayanthi, Sunarya, & Putrama, 2015). One type of e-module that can be developed is an interactive e-module that can be operated via a personal computer (PC) or laptop. E-modules contain various digital elements such as images, videos, animations, text, and audio to present molecular interactions in 3D. Interactive e-modules as learning media can help students represent sub-microscopic and symbolic levels and can improve students' visual-spatial intelligence (Rahmatsyah & Dwiningsih, 2021). Electronic interactive modules can be suitable learning media to overcome the problems above.

Based on this background, an interactive e-module is developed as learning media on intermolecular forces material. The interactive e-module is developed to produce an e-modules that can improve students' visual-spatial intelligence and can be used by students to study intermolecular forces anywhere and anytime. The feasibility of the interactive e-module will be seen from validity, effectiveness, and practicality.

Research Method

The Research and Development (R&D) method was used in this study with the ADDIE development model. There are five (5) stages at the ADDIE model, namely: (1) analysis, (2) design, (3) development, (4) implementations, and (5) evaluation (Seel, Lehnmann, Blumschein, & Podolskiy, 2017).

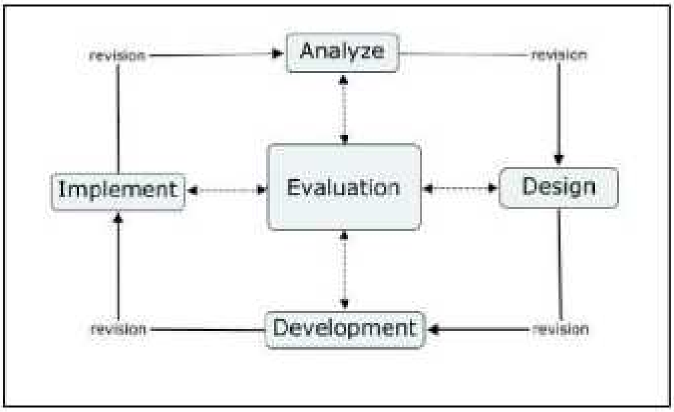

Figure 1. ADDIE Model Stage Flow

This research involved 20 tenth-grade students from SMA Muhammadiyah 2 Surabaya who were selected by purposive sampling. Obtained data from this research were analyzed descriptively quantitatively. Interactive e-module validity data were obtained through content validation and construct validation sheets, where the percentage score was obtained through a Likert scale calculation in Table 1 (Riduwan, 2016).

Table 1. Likert Scale

Scale	Category
1	Not bad
2	Less good
3	Enough
4	Good
5	Very good

To get a percentage score, the data obtained from validators were calculated using a formula that could be written:

$$P\ (\%) = \frac{total\ score}{criteria\ score}\ x\ 100$$

With:
P (%) = validation percentage

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Criteria score = highest score for each item x number of items x number of validators
The percentage of the validation sheet obtained based on the Likert scale would be interpreted with the criteria presented in Table 2.

Table 2. Validity Score Interpretation Criteria

Percentage (%)	Category
0-20	Invalid
21 -40	Less valid
41-60	Enough
60-80	Valid
81-100	Very valid

If the media developed gets a percentage for each aspect of ≥61%, the media will be stated as eligible for use in the learning process (Riduwan, 2016).

The effectiveness of the interactive e-module would then be seen through learning outcomes tests in the form of pretest and posttest. The results of the posttest were declared to have met the individual completeness score if it reached a score of 75 following the Minimum Completeness Criteria (KKM). Furthermore, the evaluation results were analyzed to determine classical completeness with classical completeness criteria 75% of students have met individual completeness scores. The value of individual completeness can be calculated using the formula:

Individual completeness = number of correct answers/number of questions

While the following formula can analyze the value of classical completeness:

N (%) = (number of students completed/number of students) x 100

Learning outcomes were then analyzed with normality test and T-test to determine the difference in the average pretest score and score posttest. The normality test was carried out by referring to the *Shapiro-Wilk* test with the help of SPSS, where the data were normally distributed if sig. 2-tailed > 0.05. T-test was carried out using Paired Sample T-Test with the help of SPSS with research hypotheses:

H_0 = The average of pretest and posttest scores has no significant difference

H_1 = The average of pretest and posttest scores has a significant difference

With the basis of decision making referring to:

H_0 is accepted if the value of sig. 2-tailed > 0.05, meaning there is no difference in the average of pretest and posttest scores.

H_0 is rejected if the value of sig. 2-tailed < 0.05, meaning there is a difference in the average of pretest and posttest scores (Sugiyono, 2015). The interactive e-module is effective if ≥75% classical completeness is achieved and there is an increase in student learning outcomes, as indicated by a significant average difference between the pretest and posttest results.

While the practicality of interactive e-modules will be seen through student response questionnaires, which will be analyzed using the Guttman scale, there are positive and negative statements in the student response questionnaire. Assessment can be done based on the Guttman scale score (Riduwan, 2016).

Table 3. Guttman Scale

Answer	Score for Positive Question	Score for Negative Question
Yes	1	0
No	0	1

To get a percentage score, the data obtained from the questionnaire were calculated using a formula that could be written:

$$\text{Response for every aspect } (\%) = \frac{\text{number of student responses to each aspect}}{\text{Number of students}} \; x\, 100$$

The questionnaire sheet obtained based on the Guttman scale were interpreted with the criteria presented in Table 4.

Table 4. Interpretation Validity Criteria Score

Percentage (%)	Category
0-20	Not good
21-40	Less good
41-60	Enough
60-80	Good
81-100	Very good

Media developed otherwise practical for use in the learning process when every aspect is ≥61% (Riduwan, 2016).

Results and Discussion

Analysis Stage

This research starts from the analysis phase. At this stage, competency analysis and an analysis of student characteristics are carried out. Competency analysis is conducted to determine Basic Competencies (KD) and indicators to limit related materials used in interactive e-modules. The material for intermolecular forces based on the 2013 revised 2017 curriculum is included in Basic Competencies 3.7 Connecting interactions between ions, atoms, and molecules with the physical properties of substances (Permendikbud, 2018). From these Basic Competencies, the indicators will include: (1) Explaining the types of forces or interactions between molecules and (2) Analyzing the relationship between interactions between molecules and the physical properties of molecules.

Analysis of student character conducted to achieve suitability of the media developed with the characteristics of students and the conditions of their learning environment. The age range of tenth-grade students ranges from 15 to 16 years. Based on Piaget's learning theory, the age range is classified as being able to reason logically and abstractly thinking to conclude from existing data or information (Ratnawati, 2015). Students are also used to operating and learning through personal computers (PCs) independently or in class based on direct observation. At the school, students are also supported by wi-fi access facilities, LCD and projectors, and a multimedia room. So that researchers assume that tenth-grade students will be able to improve their understanding through electronic learning media such as interactive e-modules.

The results of direct observations also show that the time for students to discuss with teachers and friends about learning materials in class is limited because of the reduced learning hours due to the implementation of long-distance learning. Also, the delivery of material which is often only done using-assisted lectures such as Powerpoint or textbooks without any visualization through videos or animations makes learning intermolecular forces even more ineffective and considered difficult to understand. Pre-research data also supports this observation, 90% of students think intermolecular forces material is difficult, and 70% of students prefer to study independently if they do not understand the material from class. From the results of this analysis, it is necessary to develop learning media that can help teachers deliver the material as well as become media that can be accessed and used independently by students outside of class hours. The learning media that developed can utilize online media or interactive multimedia-based media.

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From Tamami & Dwiningsih's (2020) research also Safitri & Dwiningsih's (2020), interactive multimedia, which is used flash multimedia, can provide visual intelligence stimulation that can affect students' understanding of chemistry concepts. E-modules are digital learning media that can help teachers and students in the learning process that can be used independently offline by users (Agustina, Damayanthi, Sunarya, & Putrama, 2015), and if enriched with interactive elements, it can be considered a solution to the problems. Interactive e-modules will be accessible to students anywhere and anytime offline and the interactive elements in it can increase visual-spatial intelligence.

Design Stage

The design phase is carried out by mapping the media elements and compiling the media's systematics to be developed, namely interactive e-modules. The developed e-module aims to improve students' visual-spatial intelligence. Therefore, the elements needed in the e-module are 3D illustration images, explanations in audio, 3D illustration videos, and learning videos. The e-module that will be made is designed in outline in the storyboard where the systematics of the interactive e-module are: (1) Cover, (2) Sub-Cover, (3) Preface, (4) Table of Contents, Pictures, and Tables, (5) Concept Maps, (6) Basic Competency Mapping, (7) Instructions for Using E-Modules, (8) Material and Sample Questions, (9) Summary, (10) Practice Questions, (11) Learning Videos, (12) References, and (13) Back Cover.

Development Stage

The next stage is the development stage. After compiling the material and collecting all the required media elements, interactive e-modules will be created using computer-based applications, namely MS. Word, Canva and Flip PDF. The design of the interactive e-module is shown in Figures 2, 3, 4, 5, and 6.

Figure 2. Display Cover of E-Module Interactive

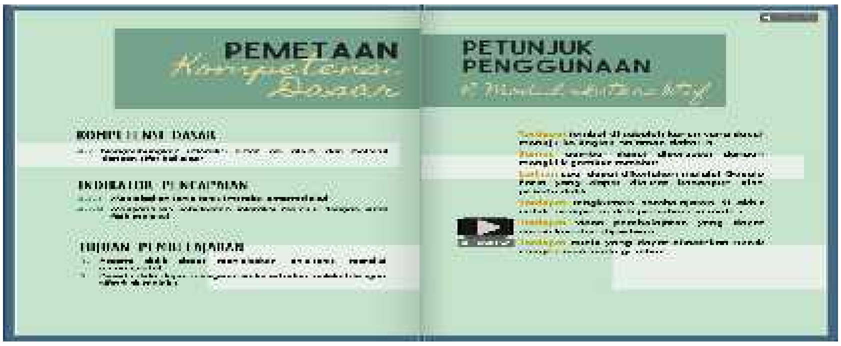

Figure 3. Display Basic Competencies Mapping and Instructions for Use E-Module Interactive

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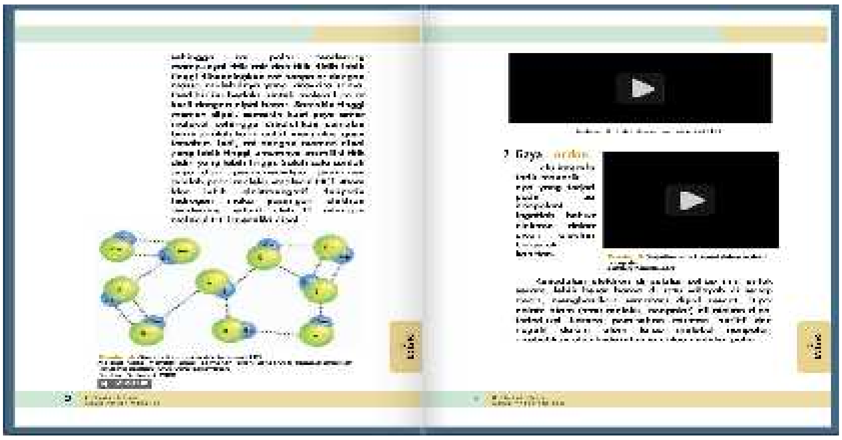

Figure 4. Display Content Equipped with Image and Video Illustrations as well as Audio Explanation

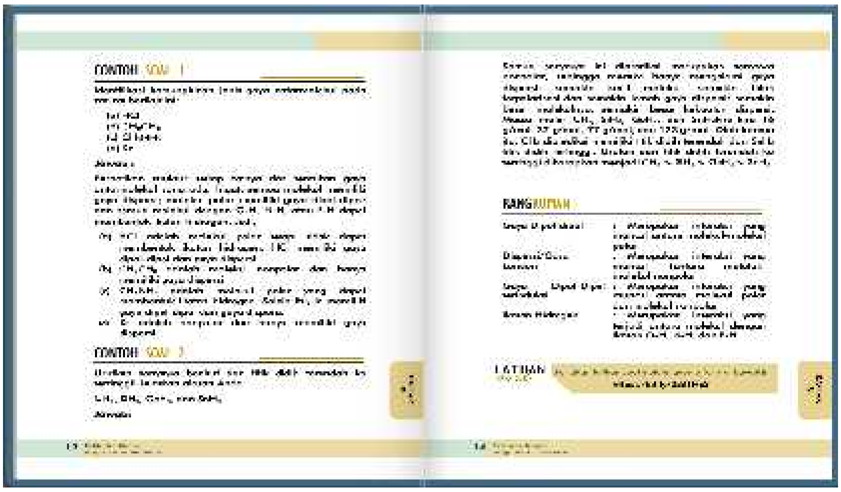

Figure 5. Display of Sample Questions, Summary, and Practice Questions

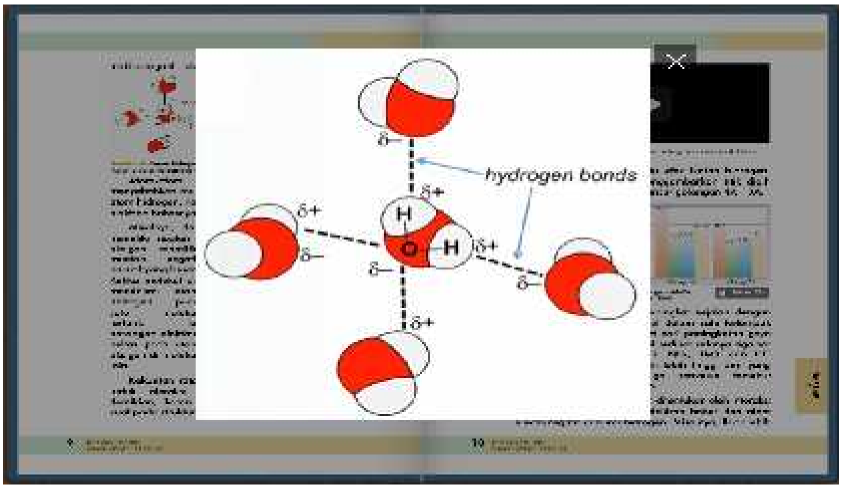

Figure 6. Display of Other Interactive Features: Pop-Up Images

Implementation Stage

At this stage, the interactive e-module has been improved according to the suggestions and input of the reviewer, which then will be given to three validators consisting of two chemistry lecturers and one high school chemistry teacher to see their feasibility from the aspect of validity. The interactive e-module validity test will be seen from the content and construct aspects. The validation results can be seen in Table 5.

Table 5. Validation Result

No	Validity	Percentage (%)	Category
1	Content	90.0	Very valid
	Material	90.0	Very valid
	Spatial Visual	90.0	Very valid
2	Construct	90.5	Very valid
	Instructional	91, 1	Very valid
	Presentation	90.4	Very valid

Based on Mayer's cognitive theory about learning to use multimedia, a multimedia design must be coherent (none irrelevant words, images, and sounds) provide cues for concepts, provide narration and animation simultaneously, put words and pictures that are sustainable, and avoid redundancy (Biffi & Woodbury, 2019).

Content validity, which must include relevance, is a feasibility test for interactive e-modules based on the suitability of the material and visual-spatial aspects of the interactive e-module. The results of content validity on material aspects contain the suitability of the material with Basic Competencies, suitability of the material with learning objectives, the coherence of the material, the scope of the material, and the suitability of the language and terms that used, get a percentage of 90.0%, which is included in the very valid category. From these results, it can be stated that the material aspects of content validity in the interactive e-module are appropriate. The suitability of the language and terms used will affect the students' understanding. If there is inappropriate language and phrases, the reader will have difficulty understanding the meaning of the writing (Ginanjar, 2020). In the visual-spatial aspect, a percentage of 90.0% is obtained with a very valid category. It can then be concluded that illustrations or animations in interactive e-modules can increase students' visual-spatial intelligence.

Construct validity, which includes the consistency aspect, is an interactive e-module feasibility test based on the conformity aspect of the instructional aspect and the presentation aspect of the interactive e-module. The instructional aspect, which includes clarity of operating guidelines, consistency of navigation buttons, and the ease of e-modules to encourage students to learn independently, gets a percentage of 91.1%, which is included in the very valid category. These results indicate that e-modules can support students to learn independently. The interactive e-module developed is to help students learn independently wherever and whenever. If the interactive e-module does not have an operating guide and has inconsistent navigation buttons, it will undoubtedly make it difficult for users to use the e-module. If students have difficulty using e-modules, of course, students cannot easily learn independently (Akbar, 2016).

The presentation aspect, which included the harmony between the color of the text and objects with background, the consistency of the color used, the accuracy of choosing the font's size and type, also the suitability of images, animations, and videos with the material, get a percentage of 90.4%. Colors that are in harmony between text and objects and the accuracy of choosing the type and size of the font on the e-module will give a good impression on students. Color harmony will make the appearance of the e-module attractive. Also, the accuracy of the size and type of font will provide comfort during use so that the fulfillment of these aspects will create a pleasant learning atmosphere (Hulu & Dwiningsih, 2021). Illustrations, images, animations, and videos have to convey their content or message

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to complement the material described. So that the images, animations, and videos used can help students improve their understanding of the material being studied.

Evaluation Stage

At this stage, interactive e-modules that have been declared suitable in learning according to the validation results are then tested for effectiveness and practicality. The practicality of the interactive e-module will be measured based on the results of the student response questionnaire. Response questionnaires were given to 20 students after they used the interactive e-module. The results of the student response questionnaires are presented in Table 6.

Table 6. Student Response Questionnaire Results

Rated Aspect	Average Percentage (%)	Category
Content	100	Very good
Language	99.2	Very good
Usefulness	97.1	Very good
Presentation	100	Very good

Every aspect has got a percentage result ≥61% so that the e-module developed based on student responses is said to be practical. Regarding the usefulness aspect, 97.1% of students agree that students are interested in using interactive e-modules because they are easy to operate. They also agree that images and videos in interactive e-modules can make it easier to understand the intermolecular forces material. So that interactive e-modules can be used to study independently.

The effectiveness of the interactive e-module was tested through the results of the pretest and posttest given. The validated interactive e-module was given to 20 tenth graders who had been selected by purposive sampling. The pretest and posttest consisted of 20 multiple choice questions, with the first ten questions regarding intermolecular forces and the second ten questions being visual-spatial questions. The pretest is given before the interactive e-module to see the students' initial ability to the material and the students' initial visual-spatial ability. In contrast, the posttest is given after students use the interactive e-module to determine student learning outcomes and students' visual-spatial intelligence after using the interactive e-module. From the pretest results, before using the interactive e-module, no student was declared complete, so classical completeness was 0%.

Table 7. Average Score of Pretest

No	Material	Average Score
1	Intermolecular forces	36.0
2	Visual-Spatial	46.6

However, after using the interactive e-module, the posttest results on the material of intermolecular forces: from 20 students who achieved KKM ≥75 and were declared complete, as many as four students still have not reached the KKM. Hence, the classical completeness obtains a percentage of 80.0%. Meanwhile, in the visual-spatial problem, from 20 students who achieved the KKM ≥75 and were declared complete, three students still had not reached the KKM and obtained the percentage of classical completeness of 85.0%.

Table 8. Average Score of Posttest

No	Material	Average Score
1	Intermolecular forces	81.5
2	Visual-Spatial	82.6

Before the T-test, the data must first be tested for normality using the *Shapiro-Wilk* normalization test with the help of SPSS. Then the data from the posttest pretest results will be T-tested to find out whether there's a significant difference between the pretest and posttest mean scores. After the data were normally distributed, the T-test was performed. The results of the T-test are presented in Table 9 and Table 10.

Table 9. T-Test for Intermolecular Forces Material Pretest Posttest

Paired Differences				**t**	**df**	**Sig. (2-tailed)**
Std. Dev.	Std. Error	95% Low	Up			
11.45931	2,56238	-50,86312	-40,13688	-17,757	19	.000

Table 10. T-Test for Visual-Spatial Pretest Posttest

Paired Differences				**t**	**df**	**Sig. (2-tailed)**
Std. Dev.	Std. Error	95% Low	Up			
13,91705	3,11195	-42,51338	-29,48662	-11,568	19	.000

Based on Table 9 and Table 10, both have a sig. 2-tailed < 0.05 where H_0 will be rejected, and H_1 will be accepted. Receipt H_1 states that there is a significant difference between pretest and posttest. A significant difference between the pretest and posttest indicates that the interactive 3D elements in the e-module affect students' visual-spatial intelligence. The use of appropriate learning media will be able to make students build their concepts independently. In addition, the use of multimedia in interactive learning can make students get vital concepts, accompanied by an increase in their visual-spatial intelligence. It is supported by the findings of Tamami & Dwiningsih (2020) that 3D illustration as an interactive element can affect students' visual-spatial intelligence significantly.

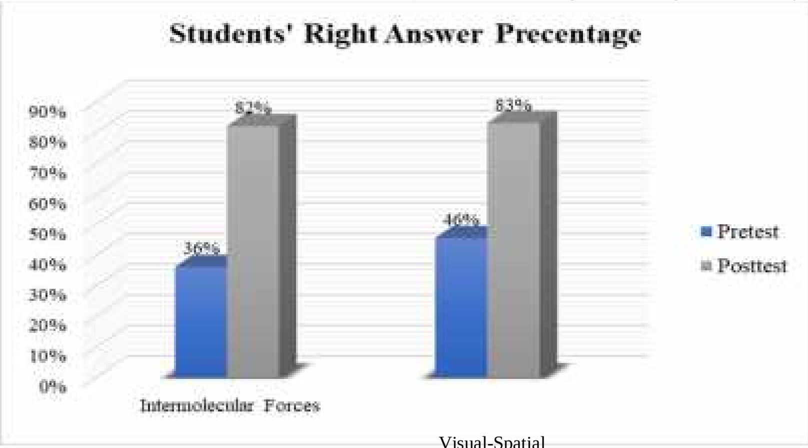

Figure 7. Students' Right Answers Percentage on The Pretest and Posttest

Following the findings of Becker, Noyes, & Cooper (2016) and the finding of Cooper, Williams, & Underwood (2015) which stated that students are still confused about interactions between molecules with interactions between atoms. Illustrations or animations about how the interaction happened between molecules will help students visualize what is actually happening. Students can have better concepts through pictures or models rather than just oral explanations. It is essential to visualize or give students a model to represent an oral explanation. It is confirmed with the findings of Ryoo, Bedell, & Swearingen (2018) that interactive molecular visualization will develop students' comprehensive understanding of molecular phenomena, and can improve their visual-spatial abilities. It is proved by the increasing posttest score of intermolecular forces, which is in line with the increase in the posttest visual-spatial score, states that the increase of students' ability to visualize objects can improve students' understanding of the material. Students will more easily absorb meaningful experiences during learning with visualization. Based on classical completeness >

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75 and the results of the T-test analysis, interactive e-modules can be said to be effective as learning media.

Conclusion

The interactive e-module is developed to produce an e-module that can improve students' visual-spatial intelligence, through this research the feasibility of the interactive e-module will be seen from validity, effectiveness, and practicality. The interactive e-module that has been developed using the ADDIE model can be said to be feasible to use in learning in terms of validity, effectiveness, and practicality. Based on the analysis of the research results, the results of the interactive e-module validation obtained a percentage of 90.0% for content validation and a percentage of 90.5% for construct validation, both of which belong to the very valid category. The effectiveness of the interactive e-module also meets the classical completeness criteria, which should be ≥75%. It gets 80.0% in the intermolecular force material and 85.0% in the visual-spatial.

The T-test results also show a significant difference between the average pretest and posttest indicated by the sig. 2-tailed value of $0.00 < 0.05$ both in terms of intermolecular forces and visual-spatial. In addition, interactive e-modules are also said to be practical to use based on student responses which show a score of 100% on the content aspect, 99.2% on the linguistic aspect, 97.1% on the usability aspect, and 100% on the presentation aspect. All of them are in the "Very good" category. This research gets the potential to be developed in further research to see the practicality of interactive e-modules better from the students' activities when using interactive e-modules in learning.

Recommendation

The research was conducted online due to distance learning. This research can be developed for further research to see the practicality of interactive e-modules better, it is possible to observe student activities when using interactive e-modules during face-to-face or offline learning.

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