JPPIPA 9(9) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Effectiveness of Android-Based Mobile Learning (M-Learning) on Molecular Shape Sub-Materials to Improve Students' Visual-Spatial Intelligence

Tito Vanzal[1], Kusumawati Dwiningsih[1*]

[1]Department of Chemistry, Faculty of Science and Mathematics, State University of Surabaya, Surabaya, Indonesia.

Received: July 19, 2023
Revised: September 20, 2023
Accepted: September 25, 2023
Published: September 30, 2023

Corresponding Author:
Kusumawati Dwiningsih
Kusuma.kimia@gmail.com

DOI: 10.29303/jppipa.v9i9.4738

Abstract: The factor causing students difficulties in understanding the shape of molecules is that students need to imagine the 3D structure of a molecule with images in 2D, so a visualization tool specifically designed to overcome problems related to this is needed. This study aims to determine the Effectiveness of Android-based M-Learning in the molecular shape sub-material to improve students' visual-spatial intelligence. This study used the 4D development model proposed by Thiagarajan (Define, Design, Develop, and Disseminate) modified by Ibrahim so that it was only carried out until the development stage. The trial of M-Learning using a One-group pretest-posttest design. The subject in this research is class IX F-3 with a number of 27 students. The effectiveness of Android-based M-Learning in terms of the increase in student learning outcomes as measured by the value of the molecular shape pretest-posttest which contains 10 multiple choice questions related to the molecular shape sub-material and visual-spatial pretest-posttest which contains 6 multiple choice questions related to spatial-visual intelligence. Research results show the molecular shape test and visual-spatial, each obtained an N-Gain of 0.63 – 1 with moderate and high feature scores. which is effective in terms of increasing student learning outcomes

Keywords: 4D Development; Effectiveness; M-Learning; Molecular Shape; Visual-spatial

Introduction

The development of science from time to time continues to grow and supports the emergence of new technologies that help humans in various fields. One area that has begun to take advantage of technological advances is Education (Lestari, 2018). In this context, smartphones, laptops, and computers are very important tools, especially in subjects such as Chemistry. The use of this technology allows quick and easy access to various information that supports the learning process (Maknuni, 2020).

Technological developments have been widely used in education, one of which is as a learning media in the classroom. One of the uses of technology-based learning media can be applied to chemistry learning. In studying chemistry, students are required to be able to relate the macroscopic properties that can be seen with the eye to the microscopic level which is invisible and relates to atoms, electrons, and molecules, and the symbolic level which relates to chemical equations and formulas, because that Most students have difficulty visualizing the material being studied (Nurviandy et al., 2020; Visser et al., 2018). One of the chemical materials that requires good visualization intelligence from students is the shape of molecules (Ika et al., 2021)

In the sub-material, the shape of a molecule requires spatial imagery and visualization of molecular representations. The study of molecular geometry includes bonds between molecules, bond lengths, and bond angles which are abstract in nature or cannot be seen with the five senses but can be studied theoretically (Nisa & Dwiningsih, 2022). This is supported by previous research which states that visualization of molecules is needed by students to help them

How to Cite:
Vanzal, T., & Dwiningsih, K. (2023). Effectiveness of Android-Based Mobile Learning (M-Learning) on Molecular Shape Sub-Materials to Improve Students' Visual-Spatial Intelligence. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7474–7483. https://doi.org/10.29303/jppipa.v9i9.4738

understand the shapes and angles of molecules (Tamami & Dwiningsih, 2020).

The ability to see or imagine something abstract is related to the intelligence possessed by each individual in visualizing virtual objects, called spatial-visual intelligence (Nisa et al 2021). Spatial-visual intelligence refers to the aptitude to effectively comprehend the form and positioning of three-dimensional objects by analyzing their two-dimensional representations (Isaloka & Dwiningsih, 2020). Students' spatial-visual intelligence influences the chemistry learning process. Sunyono and Sujarwo (2018) asserted that students with strong spatial-visual intelligence possess the ability to manipulate and interpret molecular representations in both two-dimensional and three-dimensional formats. This type of transformation is thought to enhance students' problem-solving abilities. To put it differently, spatial-visual intelligence holds significance for students studying chemistry (Rahmawati et al., 2021).

Based on the results of a pre-research questionnaire that the author conducted at Hangtuah 5 Senior High School, in the questionnaire as many as 80.6% of students said that chemistry was a difficult subject, 77.8% of students said that the molecular shape sub-material was which is quite difficult. Factors causing students' difficulties include the need for a person's mind to imagine between the 3D structure of a molecule and images printed in 2D (Isaloka & Dwiningsih, 2020). By mastering visual-spatial intelligence, students will more easily understand material regarding molecular geometry which correlates with indicators of visual-spatial intelligence (Isaloka & Dwiningsih, 2020; Nisa & Dwiningsih, 2022) Spatial visual intelligence indicators include several aspects, namely aspects; of rotation, the ability to imagine the movement of an object, symmetry, the ability to identify compounds that belong to a symmetrical compound, the interpretation of 3D molecular shapes into 2D or vice versa, the ability to imagine molecular shapes both in 2D and 3D (Achuthan et al., 2018).

Based on the explanation above, this study aims to create a learning media in the form of Android-based M-Learning that can improve students' visual-spatial intelligence, especially in molecular shape material.

Method

This study is classified as development research, specifically focusing on the creation of Android-based Mobile Learning products. It specifically concentrates on the development of Android-based Mobile Learning (M-Learning) for the sub-topic of molecular shapes. The research follows the 4D development model, originally proposed by Thiagarajan and modified by Ibrahim (2014). This model comprises four stages: Define, Design, Develop, and Disseminate. However, the scope of this particular research is limited to the Develop stage. The research design is illustrated in Figure 1.

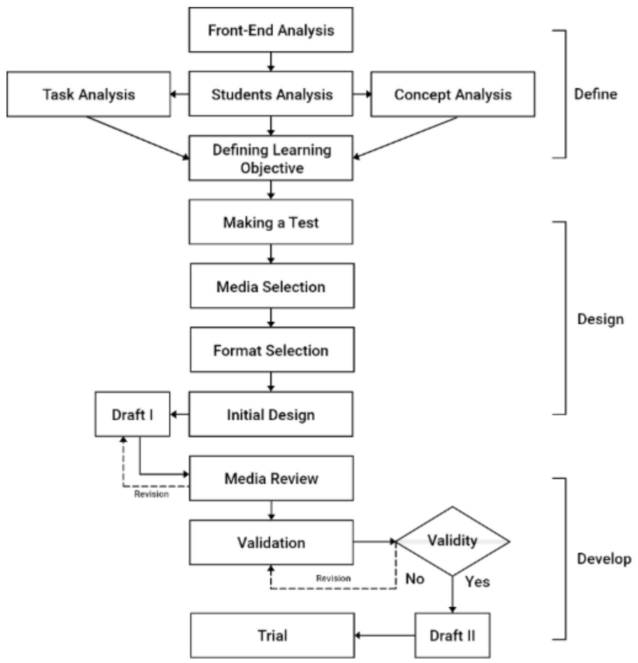

Figure 1. Thiagarajan 4D Development Research Design modified by Ibrahim (2014)

Define stage

In this phase, the analysis needs to be performed consisting of five components including: Frontend Analysis, Student Analysis, Task Analysis, Concept Analysis and Determination of Learning Objectives. In this stage, it is a primary aim to define and lay down learning conditions for the development project.

Design Stage

A number of tasks, such as test preparation, media selection, format selection and first print design, are carried out at this stage. The defined learning objectives are used to create test tools that serve as a benchmark for assessment of pupils' abilities throughout the educational process. For the purpose of identifying appropriate media that align with learning material and student needs, selection shall be carried out. This selection aims to support students in achieving the learning objectives effectively

Format selection is carried out to ensure that the chosen format suits the learning material. It encompasses designing the learning content and organizing and designing the media content, which includes layout, images, and text.

The initial design is an M-Learning media design made by researchers based on the format that has been made. This design is in the form of draft 1. At this stage use the help of Adobe XD, Unity 3D, and Blender software. Adobe XD is used to create user interfaces, Blender is used to create 3D models of molecules that will be included in Unity 3D. Unity 3D is used to implement formats and User Interfaces that have been made in Adobe XD into applications that can be installed on Android smartphones.

Development Stage

The purpose of the Development stage is to produce the revised version of M-Learning through expert input and student trials. This stage consists of two steps: media validation and limited trials. The validation process involves experts in both media and subject matter, including two chemistry lecturers and one chemistry teacher. Media validation is conducted to ensure the quality and suitability of the media before proceeding to the trial phase. The feedback obtained from this validation is utilized to enhance the developed M-Learning further.

Once the first draft is validated and revised, it leads to the creation of the second draft. The second draft, also known as Draft II, is then subjected to limited field trials with students. The purpose of these trials is to assess the effectiveness of the M-Learning. The trial design adopts a One-group pretest-posttest design. This design involves using a single group of participants and comparing their test results before and after the treatment or intervention. The One-group pretest-posttest design is employed to measure any changes in the sample group's conditions or characteristics. It can be expressed using the Equation 1.

$$O_1 \text{ x } O_2 \quad (1)$$

Description:

O_1	=	Pretest the ability of students before being given treatment
O_2	=	Posttest ability of students After being given treatment
X	=	Treatment given

Data Analysis Method

The data analysis method used in this study is mixed, namely qualitative and quantitative. Qualitative research is used at the media review stage and describes the results of validity, practicality, and effectiveness. While quantitative research is used in the practicality and effectiveness data analysis stage.

The validity of M-Learning is reviewed through the results of content and construct validity. The validator evaluates M-Learning using a Likert scale with a range of 0-4 as shown in Table 1.

Table 1. Likert Scale

Score	Category
4	Very Valid
3	Valid
2	Valid Enough
1	Invalid
0	Very Invalid

(Riduwan, 2016)

Validity results are classified as ordinal data which cannot be calculated mathematically (Lutfi, 2021). The score obtained is then determined by the mode of each validity statement. The mode is used because the validity results are classified as ordinal data. According to Lutfi (2021), ordinal data is data that cannot be operated mathematically. Ordinal data makes it possible to determine the order in which data belongs (greater than or less than) but does not allow to determine the distance between these data (Gravetter, Wallnau, Forzano, & Witnauer, 2020). So that mode can be used, the mode is used because the data obtained on the results of validity is in the form of ordinal data that cannot be carried out mathematical operations, so a decision is needed based on the largest number. M-learning is declared valid if it gets mode ≥3.

Effectiveness data were obtained from the results of students' pretest and posttest in limited trials, limited trials were conducted using a one-group pretest-posttest design. Pretest is a test conducted before students are given treatment. While the posttest is a test carried out after students are given treatment. From the results of the pretest and posttest, it will be known whether the learning outcomes of students have increased or even decreased. To determine the increase from the pretest and posttest results, you can use the N-Gain (g) formula as Formula 2.

$$g = \frac{S_{post} - S_{Pre}}{S_{maks} - S_{Pre}} \quad (2)$$

Description:

g = score N-Gain
S_{Post} = score Posttest
S_{Pre} = score Pretest
S_{maks} = score maximal

After obtaining the results of the n-gain score, it can be included in the criteria for increasing student learning outcomes in Table 4. The developed M-Learning is said to be effective if it obtains an N-Gain value ≥ 0.3.

Table 4. Improved Learning Outcomes based on N-Gain

Nilai *N Gain*	Criteria
g > 0.7	High
0.7 ≥ g ≥ 0.3	Moderate
g < 0.3	Low

Result and Discussion

The research in question employs the 4D development model, originally proposed by Thiagarajan and modified by Ibrahim (2014). This model encompasses four distinct stages: Define, Design, Develop, and Disseminate. However, the scope of this particular research is confined to the Develop stage.

Define Stage

The purpose of this stage is to establish and determine the goals and constraints for the media being developed using analysis. The define stage comprises five essential components: front-end analysis, student analysis, task analysis, concept analysis, and determination of learning objectives. The front-end analysis is conducted with the purpose of identifying and defining the fundamental issues that serve as the foundation for the development of Android-Based M-Learning. The first thing that needs to be considered is the current curriculum used, this aims to find out how chemistry lessons are carried out, especially on molecular shape material. The curriculum used at Hangtuah 5 Senior High School is independent. The next thing that must be considered is the Learning Outcomes (CP) used in this study, in the independent curriculum the chemical bond material is taught to students in class XI or it can be called phase F.

In CP phase F, chemistry subjects have general achievements, one of which includes material on molecular shapes, namely, students can learn about the structure and interactions between particles in forming a compound. Based on the results of interviews with the Hangtuah 5 Senior high school chemistry teacher, so far learning of molecular shapes is still done conventionally with the help of blackboards. In the implementation of learning that is carried out conventionally, not all students can understand what is explained by the teacher, this is because there is no clear illustration related to molecular shape material, for this reason learning media is needed that can visualize molecular shapes both in 2D and 3D.

Student analysis is one of the next analyzes that need to be done. After doing the front-end analysis. This analysis aims to determine the characteristics of students so that they become the basis for determining the Android-Based M-Learning design. The subjects in this study were students of class XI F who had not received the molecular shape sub-material. Class XI F students have an average age of over 16 years, when viewed based on Piaget's level of cognitive development, class XI F students have reached the level of formal operations. Formal operations are the last stage in Piaget's four stages of cognitive development, at this stage, students have reached a more complex, abstract, and mathematical level of thinking (Carpendale et al., 2020).

Task analysis aims to identify the various tasks required by students in operating Android-Based M-Learning. Analysis of the tasks performed by students as follows; (1) Do the pretest; (2) Operate M-Learning; (3) Study M-Learning materials; (4) Answering quizzes; (5) Do the posttest.

In concept analysis, the sub-matter of molecular shape geometry can be broken down into two concepts. The first is a molecular shape based on the valence electron pair repulsion theory (VSEPR) and hybridization theory. Both of these concepts have characteristics such as the representation and visualization of molecular shapes, which makes spatial-visual intelligence needed to make good representations.

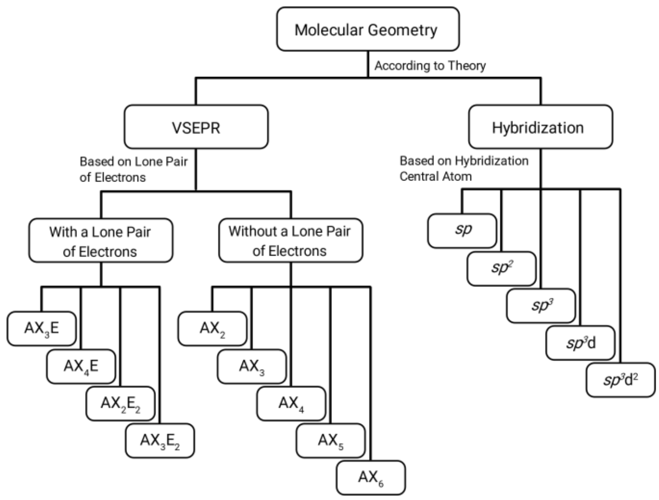

Figure 2. Molecular Shape Geometry Concept

The formulation of learning objectives is the final analysis process at the define stage. Based on the Learning Achievements of phase F in chemistry subjects, it has general achievements, one of which is that students can learn about the structure and interactions between particles in forming a compound (Kemendikbud, 2022). Based on the CP, it can be developed into learning objectives that can include the molecular shape sub-material, the learning objectives in this study are, (1) Through M-Learning students can correctly mention the shapes and angles of bonds in molecules using VSEPR theory and Hybridization theory, (2) Through M-Learning students can correctly explain the shape and angle of the bond using VSEPR theory and Hybridization theory.

Design Stage

The design stage is the next stage in the Thiagarajan 4D Development model. This stage is carried out to design learning tools including learning media and assessment instruments that are in accordance with the learning objectives that have been formulated in the define stage, including preparing tests, selecting media, selecting formats and initial media design.

The test is a method used in the context of measurements given by the teacher so that values can be produced that symbolize student learning outcomes (Rapono, Safrial, & Wijaya, 2019). The test is a series of questions that must be answered by students. Based on its implementation, the tests are divided into three types, namely, oral tests, written tests, and action or deed tests (Rapono et al., 2019). The purpose of test preparation is to assess the learning outcomes based on the established learning objectives, which serve as a benchmark for evaluating students' abilities during the learning process. Following test preparation, the next steps involve creating the test grid and scoring the test. The test grid includes scoring guidelines and answer keys for the questions. The outcome of the test preparation process is the production of written tests, including multiple-choice questions that are integrated into the M-Learning platform, as well as pretest and posttest assessments.

Media selection is carried out to identify media that matches the characteristics of the material and the characteristics of the students. This is useful to assist students in achieving learning goals. Based on a pre-research questionnaire that the author conducted at Hangtuah 5 Senior High School, as many as 97.2% of students have smartphones with Android OS, this is because the price of Android smartphones is affordable and easy to use for communication, apart from being used as a communication service provider, Android can be developed as a media student support learning. Android can be used as a learning medium which is an alternative solution that can be used in teaching and learning activities. In this case, the researcher chose the media in the form of Android-based M-Learning.

Format selection is done so that the selected format is by the learning material. Format selection in development is intended to design learning content, organizing and designing media content which includes layout, pictures, and writing. Format selection in developing Android-based M-Learning includes Splash Screen, start page, information page and instructions for use, menu page, introductory page, phenomenon page, material page, 3d molecule page, and quiz page.

The initial design is an M-Learning media design made by researchers. This design is in the form of draft 1. The initial design of the media begins with the creation of a logo, then continues with the creation of the M-Learning User Interface created using Adobe XD software, the M-Learning User Interface is created based on the format that has been made. Besides being used for creating User Interfaces, Adobe XD can also be used to create prototypes based on the User Interface that has been created.

Figure 3. M-Learning Logo

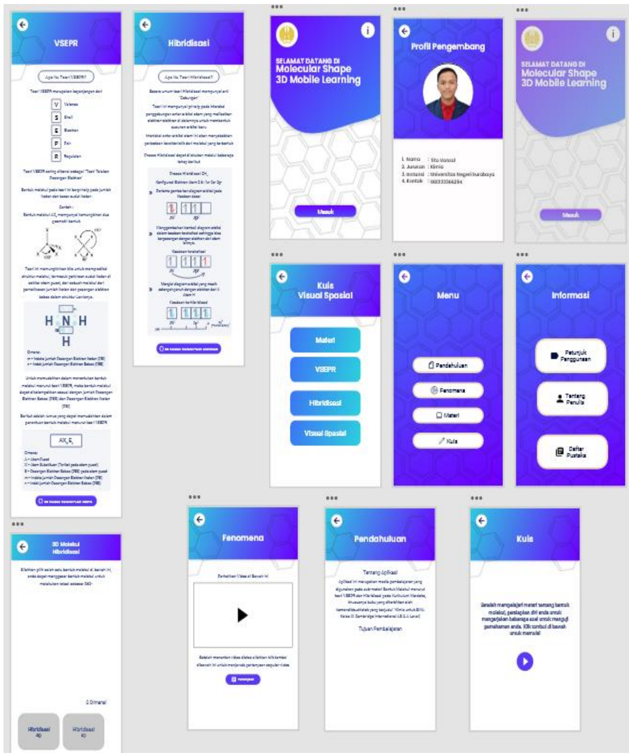

Figure 4. Android-Based M-Learning User Interface

Creating a User Interface will make it easier in the next stage, namely implementing the prototype into an application that can be installed on an Android smartphone. Making M-Learning using Unity 3D and Blender software. Blender software is used to create 3D models of molecules to be incorporated into Unity 3D. Unity 3D software is used to implement formats and User Interfaces that have been made in Adobe XD into applications that can be installed on Android smartphones. The following are the results of the initial Android-based M-Learning design made with Unity 3D and Blender.

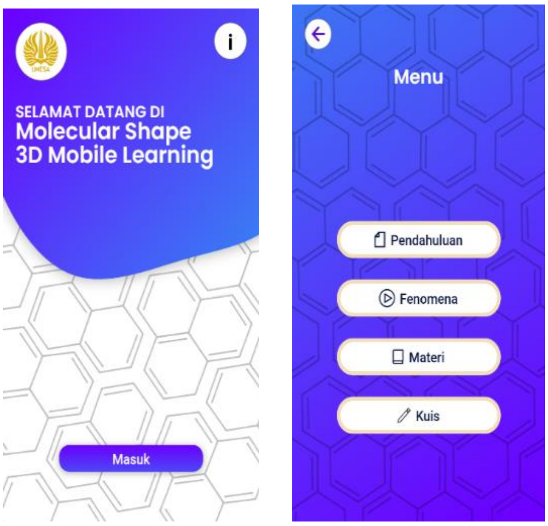

Figure 5. Initial Design of Start Page and Menu Page Draft 1

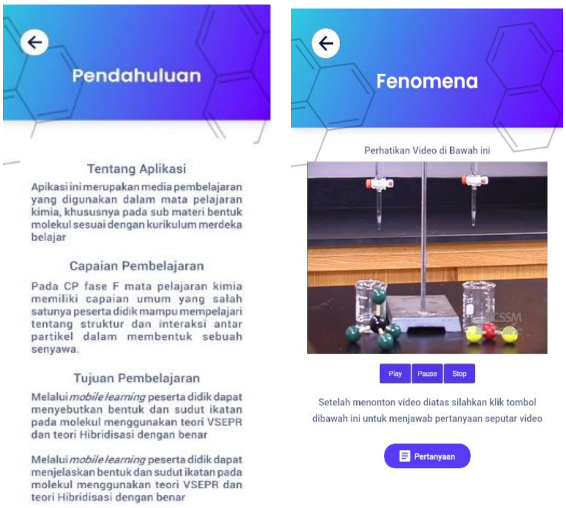

Figure 6. Initial Design of the Introduction Page and Phenomena Page

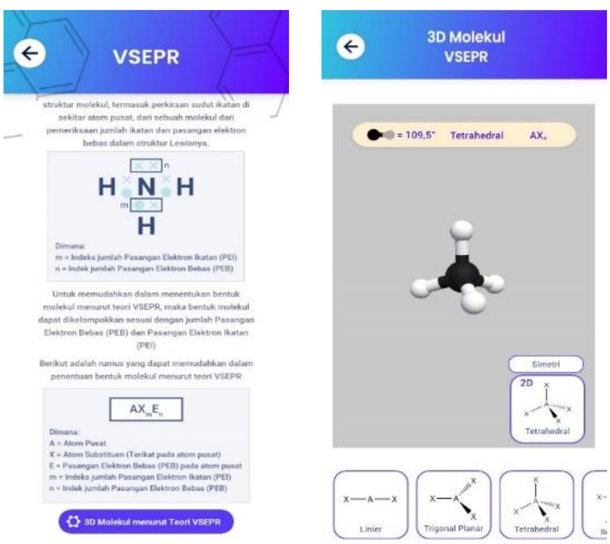

Figure 7. Preliminary Material Page Design and Molecule 3D Page

Develop Stage

The Develop stage aims to produce Android-based M-Learning which has been revised based on expert input and trials on students. At this stage, draft 1, or the initial design that has been produced is reviewed by the supervisor to provide input before the validation process is carried out. The inputs provided include adding a user prompt to open the guide when opening the application for the first time, adding a spatial visual quiz, adding a description of the symmetry of a molecule on the 3d page of the molecule, and changing the background of the text on the introductory page.

The validation stage was carried out by media experts and material experts which included 2 chemistry lecturers and 1 chemistry teacher. The aspects assessed by the validator include content validity and construct validity. The assessment was carried out using a Likert scale with a range of 0-4.

The score obtained is then determined by the mode of each validity statement. According to Lutfi (2021), ordinal data is data that cannot be operated mathematically. Ordinal data makes it possible to determine the order in which data belongs (greater than or less than) but does not allow to determine the distance between these data (Gravetter et al., 2020). So that mode can be used, the mode is used because the data obtained on the results of validity is in the form of ordinal data that cannot be carried out mathematical operations, so a decision is needed based on the largest number. M-learning is declared valid if it gets mode ≥3.

Content validity assessment indicators included the suitability of the material with the curriculum, media components, and the correctness of the material concept. Indicators for assessing construct validity include media presentation, physical media, media illustrations, and media language.

Table 5. Results of Content Validity

Assessment Indicator	Validator			Mode	Criteria
	1	2	3		
Content Validity					
Appropriateness of Material Content	3	4	4	4	Very Valid
M-Learning Components	3	3	4	3	Valid
Material Concept Accuracy	3	3	4	3	Valid
Mode	3	3	4	3	Valid

According to Table 5, the content validity of the study meets the valid eligibility criteria, as evidenced by a mode of 3. Content validity in M-Learning is conducted to assess the suitability and appropriateness of the material content, components of M-Learning, and material concepts used in the study. The results of content validity are related to the quality of the components and materials in M-Learning so that it can make it easier for students to understand the material being taught. This is in accordance with research by Sugianto (2018) and Wardhani (2022) that consistent presentation of concepts is very necessary to make it easier for students to impart knowledge.

Table 6. Results of Construct Validity

Assessment Indicator	Validator 1	Validator 2	Validator 3	Mode	Criteria
Construct Validity					
Media Presentation	4	4	4	4	Very Valid
Physical Media	3	3	4	3	Valid
Media illustration	3	3	4	3	Valid
Media language	3	3	4	3	Valid
Software Technical	4	4	4	4	Very Valid
Mode	3	3	4	3	Valid

Table 6 indicates that the construct validity of the study meets the valid eligibility criteria, with a mode of 3. Construct validity in M-Learning is conducted to assess the appropriateness and effectiveness of the media presentation, physical aspects, illustration, language, and technical aspects of the M-Learning platform used in the study. The results of construct validity relate to the physical and linguistic qualities of M-Learning so that it can attract students' attention. The integration of all visual elements such as letters, images, videos will function together to make the media more interesting when observed (Arsyad, 2015; Astuti et al., 2021; Fadli et al., 2017; Sarip et al., 2022).

Apart from that, based on the assessment of 3 validators, media language received mode 3 with the category "Valid". This shows that the M-Learning developed uses good Indonesian, is easy to understand, and the choice of sentences and words are coherent and precise. This is in accordance with research by Ovanti (2016) Learning media can be interpreted as a means to channel messages, stimulate students' thoughts, feelings, attention and will so that they can encourage the learning process, therefore it is necessary to use language according to the level of students' understanding and use of terms. correct and easy to understand.

Table 5 and Table 6 show that the content and construct validity of Android-based M-Learning obtained a mode of 3 each with valid criteria, which means that the developed M-Learning is suitable for use in limited trials.

The effectiveness of Android-based M-Learning in terms of the increase in student learning outcomes as measured by the value of the molecular shape pretest-posttest which contains 10 multiple choice questions related to the molecular shape sub-material and visual-spatial pretest-posttest which contains 6 multiple choice questions related to spatial-visual intelligence. A trial was conducted at Hangtuah 5 Senior High School class XI F-3 with 27 students.

Table 7. Results of Molecular Shape Test

Description	Pretest	Posttest
Maximum Score	30.00	100.00
Minimum Score	0.00	70.00
Avarage	19.63	80.37
N Gain		High

The pretest and posttest results for the topic of molecular shapes in the class exhibited a significant improvement in learning outcomes. This is evident from the average score of 19.63 in the pretest and 80.37 in the post-test. The M-Learning approach demonstrated a high level of effectiveness, as indicated by the N-Gain value of 0.76, which falls within the high criteria range. Based on these results the Android-based M-Learning can be declared effective because it can help students to improve learning outcomes in terms of pretest posttest competence. This is supported by research conducted by Hsin-Kai Wu and Priti Shah (2004), and Aziz Tamami (2020), namely the use of a media that presents transformations between 2D and 3D can improve student learning outcomes. This is because the use of visualization of molecular shape material can improve students' spatial-visual intelligence. The following is a graph of increasing learning outcomes based on Table 7.

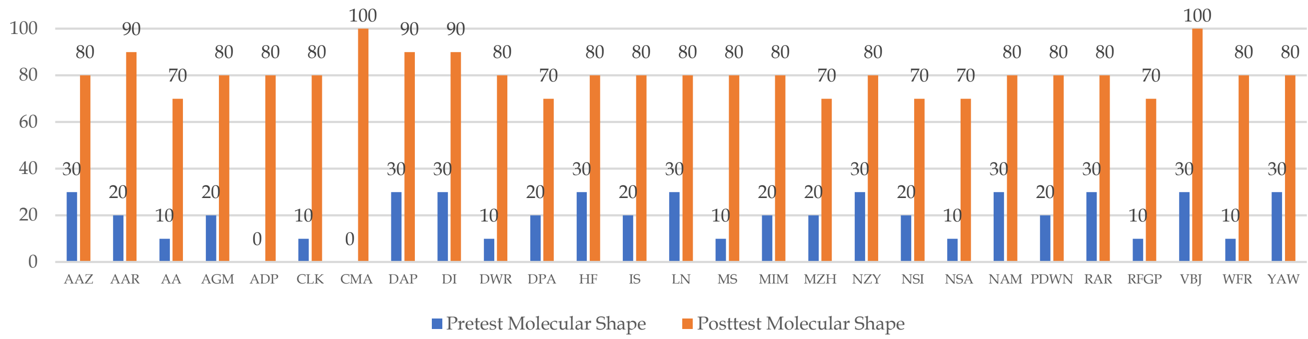

Figure 8. Graph of Improved Learning Outcomes Based on Pretest Posttest Molecular Shape

The pretest and posttest results for spatial visual abilities in the class showed a remarkable improvement in learning outcomes. This is evident from the average pretest score of 24.69 and the posttest score of 95.06. The utilization of M-Learning demonstrated a high level of effectiveness, as supported by the N-Gain value of 0.93, which meets the criteria for high effectiveness. The specific results can be observed in Table 8.

Table 8. Results of Visual Spatial Test

Description	Pretest	Posttest
Maximum Score	50.00	100.00
Minimum Score	0.00	83.33
Avarage	24.69	95.06
N Gain		High

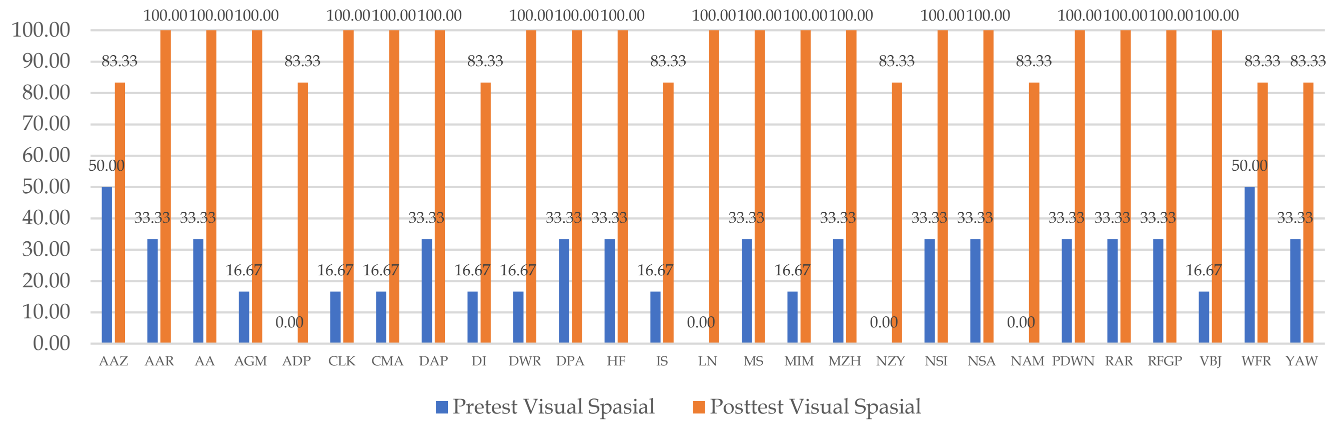

Figure 9. Graph of Improved Learning Outcomes Based on Pretest Posttest Visual-Spatial

Based on Table 8 the Android-based M-Learning developed can be declared effective because it can help students to improve learning outcomes in terms of visual-spatial pretest posttest. The results from Table 8 are also supported by Nisa's research (2021), namely that visualization media for molecular shapes are developed to be able to improve student learning outcomes. The Figure 9 is a graph of increasing learning outcomes based on Table 8.

This research shows that the results obtained are in accordance with previous research, researchers increased the range of use of a computer software developed by Aziz Tamami (2020) to become an Android application that can be used only with the help of an Android smartphone. This is also supported by research by Amirullah & Susilo (2018), android-based M-Learning can be used independently, thus enabling students to obtain information related to molecular forms of material anywhere and at any time without being limited by space and time.

Conclusion

Based on the data analysis and discussion results, it can be interpreted that Android-based M-Learning in the molecular shape sub-material can be used to improve students' visual-spatial intelligence, which effectively increases student learning outcomes. In the molecular shape test and visual-spatial, each obtained an N-Gain of 0.63 – 1 with moderate and high feature scores.

Acknowledgments
Thank you to the Chemistry Department State University of Surabaya and Hangtuah 5 Senior High School for supporting and encouraging the implementation of this research.

Author Contributions
Generating ideas, and concepts, developing, designing, and translating. Managing the entire research process, data analysis, and final editing, Tito Vanzal; Review, Dr. Kusumawati Dwiningsih, M.Pd.; Validation, Prof. Dr. Achmad Lutfi, M.Pd., Bertha Yonata, S.Pd., M.Pd., and Carissa Firdausichuuriyah, S.Pd.

Funding
This research received no external funding.

Conflicts of Interest
Authors declare no conflict of interest.

References

Achuthan, K., Kolil, V. K., & Diwakar, S. (2018). Using virtual laboratories in chemistry classrooms as interactive tools towards modifying alternate conceptions in molecular symmetry. *Education and Information Technologies*, *23*(6), 2499–2515. https://doi.org/10.1007/s10639-018-9727-1

Amirullah, G., & Susilo, S. (2018). Pengembangan Media Pembelajaran Interaktif Pada Konsep Monera

Berbasis Smartphone Android. *WACANA AKADEMIKA: Majalah Ilmiah Kependidikan*, *2*(1), 38. https://doi.org/10.30738/wa.v2i1.2555

Arsyad, A. (2015). *Media Pembelajaran*. Jakarta: Raja Grafindo Persada.

Astuti, A., Ganda, R., & Panjaitan, P. (2021). *KELAYAKAN MEDIA VIDEO PEMBELAJARAN*. *19*(2), 290–303. https://doi.org/10.31571/edukasi.v19i2.2919

Carpendale, J. I. M., Lewis, C., & Müller, U. (2020). Piaget's Theory. *The Encyclopedia of Child and Adolescent Development*, 1–11. https://doi.org/10.1002/9781119171492.wecad100

Fadli, R., Sartono, N., & Suryanda, A. (2017). Pengembangan Kamus Berbasis Sistem Operasi Telepon Pintar Pada Materi Biologi Sma Kelas Xi. *Jurnal Pendidikan Matematika Dan IPA*, *8*(2), 10. https://doi.org/10.26418/jpmipa.v8i2.21171

Gravetter, F. J., Wallnau, L. B., Forzano, L.-A. B., & Witnauer, J. E. (2020). *Essentials of Statistics for the Behavioral Sciences 10th*. Boston: Cengage Learning.

Ibrahim, M. (2014). *Ibrahim: Model Pengembangan Perangkat Pembelajaran*. Surabaya: PSMS-PPS UNESA.

Ika, P., Ritonga, A., & Gumolung, D. (2021). *Pengaruh Penggunaan Simulasi Virtual Laboratorium PhET (Physics Education Technology) Terhadap Hasil Belajar Siswa Pada Materi Geometri Molekul di MAN 1 Bitung*. *3*(2), 81–87. https://doi.org/10.37033/ojce.v3i2.288

Isaloka, I., & Dwiningsih, K. (2020). the Development of 3D Interactive Multimedia Oriented Spatial Visually on Polar and Nonpolar Covalent Bonding Materials. *JTK (Jurnal Tadris Kimiya)*, *5*(2), 153–165. https://doi.org/10.15575/jtk.v5i2.8688

Kemendikbud. (2022). Capaian Pembelajaran Mata Pelajaran Kimia Fase E - Fase F untuk SMA/MA/Program Paket C. In *Kementrian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia*. Jakarta.

Lestari, S. (2018). Peran Teknologi dalam Pendidikan di Era Globalisasi. *Edureligia; Jurnal Pendidikan Agama Islam*, *2*(2), 94–100. https://doi.org/10.33650/edureligia.v2i2.459

Lutfi, A. (2021). *Research and Development (R&D): Implikasi dalam pendidikan kimia*. Surabaya: Jurusan Kimia FMIPA UNESA.

Maknuni, J. (2020). Pengaruh Media Belajar Smartphone Terhadap Belajar Siswa Di Era Pandemi Covid-19 (The Influence of Smartphone Learning Media on Student Learning in The Era Pandemi Covid-19). *Indonesian Education Administration and Leadership Journal (IDEAL)*, *02*(02), 94–106. Retrieved from https://online-journal.unja.ac.id/IDEAL/article/view/10465

Nisa, A., & Dwiningsih, K. (2021). Efektivitas Pembelajaran Geometri Molekul Menggunakan Mobile Virtual Reality (Mvr) Untuk Meningkatkan Kemampuan Visuospasial. *Kwangsan: Jurnal Teknologi Pendidikan*, *9*(2), 220. https://doi.org/10.31800/jtp.kw.v9n2.p220--236

Nisa, A., & Dwiningsih, K. (2022). Analisis Hasil Belajar Peserta Didik Melalui Media Visualisasi Geometri Molekul Berbasis Mobile Virtual Reality (MVR). *PENDIPA Journal of Science Education*, *6*(1), 135–142. https://doi.org/10.33369/pendipa.6.1.135-142

Nisa, A., Rifki, I. Y., Alya, A., & Dwiningsih, K. (2021). The Validity of Molecular Geometry Based Virtual Reality to Improve Student Visual-Spatial Intelligence in New Normal Era. *Journal of Educational Sciences*, *5*(3), 393. https://doi.org/10.31258/jes.5.3.p.393-408

Nurviandy, I., Dwiningsih, K., Habibi, A. R., & Akbar, A. F. (2020). *Validity of Interactive Multimedia with 3D Visualization to Practice the Spatial Visual Intelligence of Class X High School Students on Metallic Bonding Materials*. *1*(Snk), 140–144. https://doi.org/10.2991/snk-19.2019.33

Ovanti A.P, R., & Dwiningsih, K. (2016). Developing Multimedia Interactive Based Blended Learning At Kimia Subject Class XII. *Proceedings of International Research Clinic & Scientific Publications of Educational Technology*, *1*(1), 775–781.

Rahmawati, Y., Dianhar, H., & Arifin, F. (2021). Analysing students' spatial abilities in chemistry learning using 3d virtual representation. *Education Sciences*, *11*(4). https://doi.org/10.3390/educsci11040185

Rapono, M., Safrial, S., & Wijaya, C. (2019). Urgensi Penyusunan Tes Hasil Belajar: Upaya Menemukan Formulasi Tes Yang Baik dan Benar. *Jupiis: Jurnal Pendidikan Ilmu-Ilmu Sosial*, *11*(1), 95. https://doi.org/10.24114/jupiis.v11i1.12227

Riduwan. (2016). Skala Pengukuran Bandung Variabel Variabel Penelitian. In *Alfabeta*. Bandung: Alfabeta.

Sarip, M., Amintarti, S., & Utami, N. H. (2022). Validitas dan Keterbacaan Media Ajar E-Booklet untuk Siswa SMA / MA Materi Keanekaragaman Hayati. *JUPEIS: Jurnal Pendidikan Dan Ilmu Sosial*, *1*(1), 43–59. https://doi.org/10.55784/jupeis.Vol1.Iss1

Sugianto, S. D., Ahied, M., Hadi, W. P., & Wulandari, A. Y. R. (2018). Pengembangan Modul Ipa Berbasis Proyek Terintegrasi Stem Pada Materi Tekanan. *Natural Science Education Research*, *1*(1), 28–39. https://doi.org/10.21107/nser.v1i1.4171

Sunyono, S., & Sudjarwo, S. (2018). Mental models of atomic structure concepts of 11th grade chemistry students. *Asia-Pacific Forum on Science Learning and Teaching*, *19*(1).

Tamami, A. A., & Dwiningsih, K. (2020a). 3-Dimensions Of Interactive Multimedia Validityto Increase

Visual-Spatial Intelligence In Molecular Geometry. *Jurnal Kependidikan: Penelitian Inovasi Pembelajaran*, *2*(2), 241–255. https://doi.org/https://doi.org/10.21831/jk.v4i2.31222

Tamami, A. A., & Dwiningsih, K. (2020b). The Effectivity of 3D Interactive Multimedia to Increase the Students' Visuospatial Abilities in Molecular. *Jurnal Pendidikan Dan Pengajaran*, *53*(3), 307. https://doi.org/10.23887/jpp.v53i3.25883

Visser, T., Maaswinkel, T., Coenders, F., & McKenney, S. (2018). Writing Prompts Help Improve Expression of Conceptual Understanding in Chemistry. *Journal of Chemical Education*, *95*(8), 1331–1335. https://doi.org/10.1021/acs.jchemed.7b00798

Wardhani, F. P., Islamiyah, H. Y., Zulfadilla, I., Mukhlis, M., & Riau, U. I. (2022). Analisis Kelayakan Penyajian Buku Teks Bahasa Indonesia Kelas XI Kurikulum 2013 Edisi Revisi 2017. *Jurnal Penelitian Dan Pengabdian Sastra, Bahasa, Dan Pendidikan*, *1*(1), 156–167. https://doi.org/10.25299/s.v1i1.8828

Wu, H. K., & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education*, *88*(3), 465–492. https://doi.org/10.1002/sce.10126