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The Effectiveness of *Uno Kimia* Cards in Enhancing Understanding of Molecular Shape Topic Among High School Students

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Abstract. Understanding molecular shapes poses significant challenging for students due to the abstract nature of the topic, which can limit engagement and comprehension. This study aims to investigate the effectiveness of uno kimia (Umia) cards as an instructional tool to enhance students' comprehension on students' understanding of the molecular shapes topic at SMA Negeri 1 Mentebah. The study used a quasi-experimental design with a nonrandomized control pre-test and post-test was utilized, involving sixty tenth-grade students divided into experimental group using Umia cards and control groups employing traditional teaching methods. Learning outcomes were assessed using validated pre-test and post-test instruments, with content validity index scores of 0.88 and 0.82 for the teaching module, both results confirming the instruments were valid. The chi-square test revealed no significant difference in the control group ($p = 0.504$), while the experimental group using Umia cards showed significant improvement ($p = 0.007$). A non-parametric Mann-Whitney U test indicated homogeneity between the groups ($p = 0.982$). Results showed significant improvement in the experimental group's understanding, with an 88% increase, a high effect size (Cohen's $d = 1.259$), and a high N-gain score (mean = 0.7106) compared to the control group (mean = 0.4103). The findings indicate that the Umia cards are a highly effective pedagogical tool, capable of improving both student engagement and conceptual understanding in molecular shape topic. These results underscore the potential of interactive learning media in addressing challenges associated.

Keywords: Effectiveness, molecular shape, uno kimia cards

Introduction

Chemistry is a fundamental subject in secondary education, playing a crucial role in fostering students' logical, analytical, systematic, critical, and creative thinking abilities (Rosa, 2015). Mastering chemistry involves connecting microscopic details such as molecules, atoms, and orbitals to macroscopic phenomena (Levy et al., 2024). However, the subject's complexity lies in its abstract concepts, particularly the molecular and sub-microscopic explanations of matter's properties, structures, and behaviours. Among these, the topic of molecular shapes, which requires predicting and determining molecular geometry using the VSEPR theory, poses significant challenges due to its abstract nature

(Erlina et al., 2024). This topic explores molecular structures and characteristics, emphasizing how these features influence the properties and reactivity of chemical compounds. A key aspect of molecular shapes is their three-dimensional structure, determined by the number of bonds and bond angles around central atoms (Siregar & Harahap, 2020).

Based on interviews conducted at SMA Negeri 1 Mentebah, teacher highlighted that students face significant challenges in understanding molecular shapes, particularly when applying the VSEPR theory. These challenges include low student engagement, difficulty grasping abstract concepts, limited learning media, insufficient teaching strategies, and poor learning outcomes. Previous research has indicated that determining molecular structures presents challenges for some students. Misconceptions further hinder students' ability to represent molecular shapes at the microscopic level, complicating their understanding of molecular geometry's abstract nature (Siregar & Wiyarsi, 2024; Yovanie, 2025; Agung et al., 2024; Kiernan et al., 2024; Santos et al., 2024). Visualizing molecules in three dimensions is one of the most challenging tasks for both students and teachers (Levy et al., 2024).

Research suggest that interactive media can enhance student motivation and comprehence in learning process (Fisher et al., 2022), that relies on students' ability to solve problems in the classroom, facilitated by meaningful interactions between teachers and students (Rohmawati, 2015). This effectiveness serves as a critical indicator of the success of instructional models (Yang & Du, 2024). In chemistry education, understanding complex concepts such as the basic laws of chemistry, elements and compounds, and chemical reactions requires effective instructional strategies. Instructional media play a significant role in this context. According to Hamalik (1994), instructional media, whether human or inanimate, enhance communication between learners and educators, aiding comprehension of the subject matter. Effective instructional media can boost student interest, motivation, and enthusiasm, which are crucial for mastering intricate chemical concepts (Cotiangco et al., 2024).

Therefore, to address these challenges, this study proposes the use of Umia cards as an interactive learning medium. Inspired by the Umia card game yet it modified to molecular shapes concepts, the Umia cards were developed using the ADDIE model (analyze, design, development, implementation, and evaluation), while the initial study was limited to development stage, and further stages have not investigated. The initial development and validation of Umia cards showed promising results, with a validation score of 97.22% and positive responses from both students (86.90%) and teachers (94.64%). These findings suggest that Umia cards are valid, practical, and well-received instructional tools, suitable for further implementation and evaluation stage to determine their effectiveness.

This study aims to evaluate the effectiveness of Umia cards in enhancing students' understanding of molecular shapes topic at SMA Negeri 1 Mentebah. By addressing gaps in instructional strategies and providing evidence-based insights, this research seeks to advance the integration of interactive media in chemistry education and contribute to improving learning outcomes in abstract scientific topics.

Methods

The research method utilized is the quasi-experimental design (Subekti et al., 2021), with the nonrandomized control pretest-posttest design (Sugiyono, 2013). The research design is outlined can be seen on Table 1.

Table 1. The nonrandomized control group pretest-posttest design

Group	Pre-test	Treatment	Post-test
Experimental	E_1	X_1	T_2
Control	C1	-	T_2

(Source: Rahman et al., 2022)

Experimental research involves examining the impact of particular behaviours on other variables within controlled conditions which explores treatments in one or more groups without employing complete randomization, as seen in true experiments (Maciejewski et al., 2020). This design choice aims to assess the initial condition, examining potential differences between the experimental and control groups before treatment. The experimental group receives treatment using Umia card learning media for molecular shapes material, while the control group receives no specific learning media. Both groups fulfilled a pretest before treatment, followed by a post-test after treatment, with identical questions and time assigned to complete both tests. Subsequently, the results are compared to determine more effective methods for enhancing student learning outcomes.

The research conducted at SMA Negeri 1 Mentebah, The population consists of all tenth-grade students, comprising 4 classes with a total 122 students. The sample for this research comprises two classes, that are class C and D with total are 60 students. This study used non-probability sampling. Specifically purposive sampling was utilized to allow selection based on specific criteria determined by the teacher. In this case, classes tenth C and D were chosen due to their high level of student participation, as observed by the chemistry teacher. This sampling method offers flexibility and allows for targeted selection based on relevant characteristics.

The independent variable in this study is the use of Umia cards in teaching, while the dependent variable is the students' learning outcomes in the topic of molecular shapes. The research aims to determine the impact of employing Umia cards on students' comprehension. By comparing the performance of students who learn with Umia cards to those who receive traditional instruction, the study seeks to measure the effectiveness of this innovative teaching tool in enhancing educational outcomes. The expectation is that the interactive and visual nature of Umia cards will significantly improve students' understanding and engagement, leading to better academic performance in this complex topic.

The implementation procedure in this research consists of three stages: the initial stage, the implementation stage, and the final stage. The research procedure can be seen in Figure 1. In the initial stage, the learning outcomes are analyzed, teaching module and pre-test post-test question are created, research instruments are developed, validated, revised, necessary tools and materials are prepared. The implementation stage involves conducting homogeneity tests, selecting experimental and control groups, administering pre-tests, and implementing teaching methods in both groups. Finally, in the final stage, post-test are administered, data is analyzed, discussions are conducted, and conclusions are drawn. Throughout the process, various steps ensure the systematic implementation of the research, including validation of instruments and careful selection of experimental and control groups.

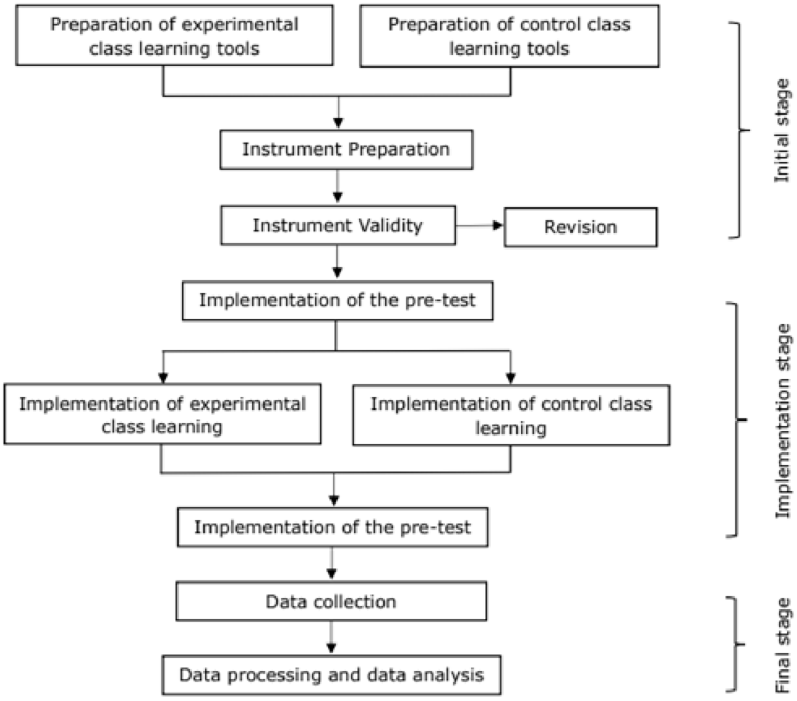

Figure 1. The Procedure of Research

In this study, a pre-test post-test design is employed to measure the impact of using Umia cards on students learning outcomes regarding molecular shape topic. The pre-test assesses students' prior knowledge, while the posttest evaluates their final ability after the treatment. Both tests consist of 10 multiple-choice questions aligned with specific learning objectives related to molecular shapes. The aim is to determine whether there is a difference in learning outcomes between the control and experimental groups, thus measuring the effectiveness of Umia card media. The questions are constructed based on Bloom's cognitive domain, focusing on knowledge, understanding, and application aspects.

The data analysis techniques employed in this study encompass a variety of statistical tests to ensure the validity, reliability, normality, and homogeneity of the data, as well as to measure the improvement and impact of the instructional media used. The data were analyzed using SPSS 29.0.2.0 for windows. Validation tests include both module and test item validation to confirm that the instruments align with the research objectives (Alvianita et al., 2022). Reliability testing is conducted to assess the consistency of the test items (Kumar et al., 2021). Normality tests are used to determine whether the data follow a normal distribution (Khatun, 2021). Homogeneity tests ensure that the variances between the experimental and control groups are equivalent (Curtis et al., 2022). The N-gain test measures the improvement in learning outcomes before and after the intervention (Hikmah & Ahmad, 2020). Finally, the effect size test quantifies the magnitude of the impact that the instructional media have on students' learning outcomes (Antonio, 2022).

The validity testing of instruments involves comparing their content with the subject matter taught. Content validity is evaluated against established substance or design for instruments assessing program implementation effectiveness (Utaminingsih et al., 2024). This study validated instruments such as teaching modules, and pre-test post-test questions. Validity ensures instruments accurately measure intended aspects, with higher validity indicating greater accuracy and reliability. According to Gregory, multiple experts can assess the content validity coefficient qualitatively and quantitatively.

Table 2. Cross-tabulation 2X2 content validity according to Gregory

Content Validity		*Rater* 2	
		Less relevant (Scores 1-2)	Strongly relevant (Scores 3-4)
Rater 1	Less Relevant (Scores 1-2)	(A)	(B)
	Strongly relevant (Scores 3-4)	(C)	(D)

(Source: Wirasmika et al., 2023)

Explanation:

VC : Content Validity

A : both expert reviewers disagree

B : expert reviewer 1 agrees, Expert reviewer 2 disagrees

C : expert reviewer 1 disagrees, Expert reviewer 2 agrees

D : both experts reviewers agree

Content validity is calculated by taking the number of items that receive agreement from both experts (in column D) and dividing it by the total number of items evaluated by both experts (the total of columns A, B, C, and D). This indicates how often items receive. Agreement from both experts regarding the content or substance of the tested instrument. The formula is as follows:

$$VC = \frac{D}{A + B + C + D}$$

The interpretation of results content validity is as follows:

Table 3. Criteria of Validity Content

Validity Content	Category
0.80 – 1.00	Strongly High
0.60 – 0.79	High
0.40 – 0.59	Medium
0.20 – 0.39	Low
0.00 – 0.19	Strongly Low

(Source: Wirasmika et. al., 2023)

The valid questions will proceed to the next stage, which is testing the reliability. Basically, reliability testing measures the variables used through the questions employed. Reliability testing is conducted by comparing the Cronbach's alpha value with the significance level, ranging from 0.5 or 0.6 to 0.7, depending on the research needs (Govindasamy et al., 2024). The testing criteria are as If the Cronbach's alpha value > the significance level, then the instrument is considered reliable or vise versa. Using the same set of questions in the validity test above, assuming that all questions are valid (Darma, 2021). The calculation using the Cronbach's alpha formula is accepted if the calculated r value > the tabled r value at 5% significance level (Janna & Herianto, 2021).

Normality test is used to evaluate whether both groups have a normal distribution (Parekh, 2024; Fitria & Waswa, 2024; Fiandini et al., 2024). If both sets of data analyzed have a normal distribution, the next step is to conduct a parametric test, namely the test of variance homogeneity (Fiandini et al., 2024). However, suppose one or both data analyzed set do not have a normal distribution. Before analyzing data using the t-test, it is important to test the normality of the data from the test with the chi-square test. If $\chi 2$ calculated $\leq$ $\chi 2$ table, it is concluded that the data follows a normal distribution or vise versa. After meeting this requirement, the data can be processed using the formula for the t-test.

Homogeneity test is a method used to examine whether various variances from populations have similarities or differences (Fiandini et al., 2024). The test of equality of two variances plays a role in assessing whether the data distribution is homogeneous by comparing these two variances. If two or more data groups have nearly identical variances, then a homogeneity test may not be necessary because the data is considered homogeneous (Kabbillawsh et al., 2024). After analyzing the data, the next step is to conduct a hypothesis test to determine whether there is a difference in the mean abilities between the experimental and control groups. If the calculated t_{value} is greater than or equal to the critical t_{table}, then the null hypothesis will be rejected or vise versa (Okoye & Hosseini, 2024).

The N-gain calculation, rooted in the pre-test and post-test scores obtained from both the experimental and control classes, serves as a robust metric for assessing the extent of improvement in students' competencies following the learning process (Rahman et al., 2024). The N-gain analysis quantifies the effectiveness of instructional strategies by measuring students' knowledge acquisition and conceptual understanding before and after the learning activity. The formula for calculating the N-gain, as proposed by Meltzer as follows:

$$\mathrm{N-gain} = \frac{\mathrm{s_{post}} - \mathrm{s_{pre}}}{\mathrm{s_{mask}} - \mathrm{s_{pre}}}$$

Explanation:
N-gain : gain normality test value
S_{post} : post-test Score
S_{pre} : pre-test Score
S_{maks} : Maximum Score
(Wahab et al., 2021)

The interpretation of N-gain according to Hake (1999) will be categorized as follows:

Table 4. Interpretation of N-gain score

Average	Category
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	medium
$0 < g < 0.3$	low
$g \leq 0$	Failed

(Source : Hake, 1999)

Effect size analysis will be carried out to determine the influence of using teaching materials on student learning motivation (Wijinia,2024; Zeng & Luo, 2024; Doo & Zhu, 2024) . To determine the effect of each research data, the Jacob Cohen equation will be utilized as follows:

$$ES = \frac{(\overline{X}\,\text{post} - \overline{X}\,\text{pre})_E - (\overline{X}\,\text{post} - \overline{X}\,\text{pre})_C}{\frac{\text{SD pre C}+\text{SD pre E} + \text{SD post C}}{3}}$$

Explanation :
ES : Effect Size
$\overline{X}$ pre : Pretest average score
$\overline{X}$ post : Average posttest score
SD pre : Standard deviation of pretest
SD post : Posttest Standard Deviation
(Source: Cohen,1988)

After the effect size is calculated, the interpretation of the calculation results will be categorized at the following levels:

Table 5. Criteria of effect size

Effect Size	Category
$0 \leq ES \leq 0.2$	low
$0.2 \leq ES \leq 0.8$	medium
$ES \geq 0.8$	high

(Source: Cohen,1988)

Results and Discussion

The pre-test and post-test assessments contain 10 questions designed to measure students' learning outcomes. To ensure that these questions are appropriate and effective for use to students, a validation process is necessary. This process evaluates the questions against various criteria to ensure they are suitable for measuring the intended learning objectives. Specifically, the content validity of the pre-test and post-test questions was assessed based on 5 distinct criteria. The results of this content validity assessment are summarized in the Table 6. This thorough validation ensures that each question accurately reflects the learning objective and provides reliable data for evaluating student progress.

Based the Table 6, the evaluation of validity aspects as measured using the content validity index (CVI), demonstrates a high degree of alignment and validity. The alignment of indicators with learning objectives, and of questions with indicators, both received a CVI score of 0.7 which is categorized as high. This indicates that the learning indicators and questions are well-designed to match the intended learning objectives and indicators. Indicators are used as a basis or reference in developing an evaluation tool for the topic of molecular shapes. A test item is considered appropriate if it aligns with the indicators and effectively assesses the targeted learning objectives and content (Mauliandri et al., 2021).

Furthermore, the alignment of answer keys and scoring guidelines with questions, the alignment of questions with the cognitive domain, and the alignment of the scoring guideline descriptions all received a perfect CVI score of 1.00, categorized as strongly high. This signifies that the answer keys, scoring guidelines, and descriptions are exceptionally well-aligned, ensuring accurate and consistent scoring. Clear criteria will assist developers in producing accurate scoring guidelines, ensuring that the resulting assessments are fair and equitable (Johnson et al., 2008).

Table 6. The results CVI of questions

Evaluation Aspects	CVI	Category
The alignment of indicators with learning objectives	0.7	High
The alignment of questions with indicator	0.7	High
The alignment of answer keys/scoring guidelines with questions	1.00	Strongly High
The alignment of question with cognitive domain	1.00	Strongly High
The alignment of the scoring guideline description	1.00	Strongly High
Average	0.88	Strongly High

The total average of questions pre-test post-test with CVI score of 0.88 falls into the strongly high category, affirming that all components of the evaluation aspects are highly aligned. This strong alignment enhances the validity of the assessment instruments, ensuring that they effectively measure the intended learning outcomes. Consequently, the assessment instruments used are highly effective in evaluating learning objective, providing an accurate representation of students' understanding and competencies. Valid measurement outcomes can be utilized to develop more effective learning programs or interventions. These programs are grounded in accurate data and can yield better outcomes for students (Fraser et al., 2009).

Table 7. The evaluation aspects of teaching module

Evaluation Aspects	Number of Items
Identity	1, 2
Formulation of Learning Objectives and Indicators	3, 4, 5, 6, 7, 8, 9
Material Selection	10, 11, 12
Selection of teaching methods	13, 14
Planning of Learning Activities	15, 16
Selection of Learning Resources	17, 18
Developing Assessments	19, 20
Language	21, 22, 23

The teaching module is evaluated across 8 different aspects, encompassing a total of 23 items. The CVI score for the teaching module is 0.82, classified as strongly high. This reflects excellent alignment with its intended learning objectives. Evaluation aspects of the module include defining clear learning goals, selecting appropriate materials and teaching methods, planning effective activities, choosing relevant resources, designing assessments, and ensuring clarity of language. This comprehensive evaluation ensures each component supports students in achieving desired learning outcomes, highlighting the module's valid in facilitating a coherent learning experience.

instructional module demonstrates several key characteristics that enhance its effectiveness in education. An instructional module that aligns with learning objectives ensures that students can understand and apply the taught material accurately (Ningsih et al., 2023). Integration with existing curriculum and adherence to educational standards promote comprehensive understanding of relevant topics (Gouedard et al., 2020).

Once the test questions and learning module are deemed valid, the data are considered suitable for further testing. The test questions are then evaluated to determine whether the instrument is reliable and appropriate for use in the research. The reliability test of the questions was conducted on a class of 25 students from class XI IPA who have studied the topic of molecular shapes. A Cronbach's Alpha value of 0.729 indicates acceptable internal consistency reliability for the scale. Generally, a Cronbach's Alpha value > 0.5 is considered acceptable, suggesting that the items on the scale measure the same underlying construct and are sufficiently correlated with each other. Reliable questions indicate that the measurement outcomes obtained from their use are consistent and dependable. This means that if these questions are used repeatedly, the results obtained will be similar and predictably accurate. The use of reliable questions can provide strong reliability, allowing them to be confidently used to interpret research findings (Schrepp, 2020).

Valid questions and instructional modules can be effectively utilized in research. Valid questions ensure that the data collected accurately measures what it intends to assess, contributing to the reliability and validity of the research outcomes. Valid instructional modules, on the other hand, ensure that the educational interventions or learning materials used in the research align closely with the learning objectives and standards, thereby influencing the effectiveness of the study's outcomes. By using both valid questions and instructional modules, researchers can enhance the quality and credibility of their research findings.

Confirming the instrument is valid and reliable, it is deemed suitable for use with students in the research. Before proceeding with the actual research, it is essential to conduct normality and homogeneity tests. These tests are necessary to ensure that the data distribution is normal and that the variance among different groups is homogeneous. The normality and homogeneity tests are determined by analyzing the pre-test results of students' learning outcomes. Conducting these tests helps in validating the assumptions required for subsequent statistical analyses, thereby ensuring the robustness and accuracy of the research findings.

Table 8. The normality (Chi-Square) test (N=30)

	Control	Experimental
Chi-Square	3.333[a]	16.000[a]
Df	4	5
Asymp. Sig.	0.504	0.007

The Chi-Square test for the control group showed on Table 8, a Chi-Square with an asymptotic significance (Asymp. Sig.) value of 0.504 is greater than the significance level of 0.05, we fail to reject the null hypothesis. This indicates that there is no statistically significant difference between the categories in the control group. The Chi-Square test for the experimental group showed a Chi-Square with an asymptotic significance (Asymp. Sig.) value of 0.007 is less than the significance level of 0.05, we reject the null hypothesis. This indicates that there is a statistically significant difference between the categories in the experimental group.

Given that the control class follows a normal distribution while the experimental class does not, the subsequent analysis will involve a homogeneity test using a non-parametric with the Mann-Whitney U test. Based on Table 9 the p-value (Asymp. Sig.) of 0.982 ≥ 0.05, we fail to reject the null hypothesis. This indicates that there is no statistically significant difference between the two groups. The scores of the two groups are similar, suggesting that the intervention or condition being tested did not lead to a significant difference in the measured outcome between the groups.

Table 9. The homogeneity (Mann-Whitney U) test (N=60)

	Score	t_{table}
Mann-Whitney U	448.500	2.042
Wilcoxon W	913.500	
Z	-0.023	
Asymp. Sig. (2-tailed)	0.982	

The finding that both classes demonstrate homogeneity indicates they are suitable for advancing to the next phase of testing. The subsequent step involves in implementing the Umia cards intervention in the experimental class, while the control class will utilize molymod for comparison purposes. This intervention seeks to assess the effectiveness of each media in enhancing students' understanding of the topic. By employing these distinct methods under comparable conditions, the study aims to offer deeper insights into the advantages and limitations of each instructional approach.

The pre-test and post-test assessments have been administered, and the data has been successfully collected. This data serves as the foundation for analyzing students' learning outcomes. By comparing the results of the pre-test and post-test, researchers can evaluate the extent of students' progress and identify the effectiveness of the instructional methods or interventions applied during the study. This analysis not only highlights areas of improvement but also provides insights into the overall impact of the educational strategies on students' understanding and performance.

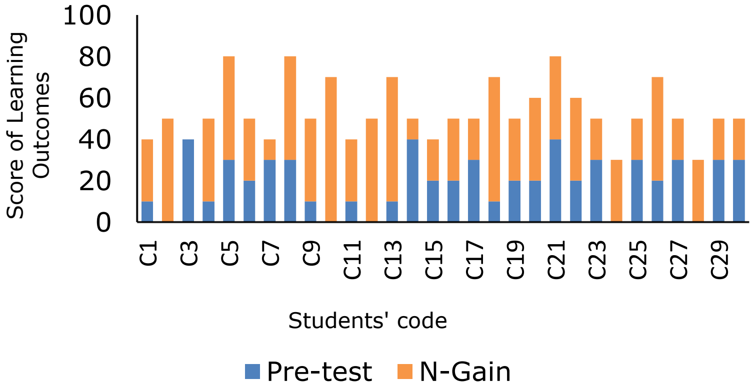

Figure 2. Students' learning outcomes of control group (N=30)

The analysis of the N-gain scores for both the control and experimental classes reveals significant differences in the effectiveness of their respective interventions, providing deeper insights into how different instructional tools can impact student learning outcomes. Based on Table 10, the control class, which utilized molymod, achieved an average N-gain score of 0.4103, categorized as "medium". This moderate improvement suggests that while molymod proved effective to some extent, its impact was less pronounced compared to the experimental group. Molymod is an interactive learning tool designed to help students visualize molecular shapes in three dimensions. It facilitates engagement with molecular structures, offering visual representations of how molecules are formed and behave. While this approach aids in understanding abstract concepts in chemistry (Istiningrum & Wiyantoko, 2017; Sausan et al., 2020; Erlina et al., 2018), it primarily focuses on the visualization aspect. However, it lacks in-depth explanations of molecular formation processes and interactions, which may have limited its ability to foster a deeper understanding of the subject. The tool's ability to support conceptual mastery, though valuable, falls short of addressing the intricacies of molecular behavior, which is crucial for comprehensive chemistry learning.

Table 10. The N-gain test

Class	N	Minimum	Maximum	N-gain Score
Control	30	0.00	0.71	0.4103
Experimental	30	0.29	1.00	0.7106

In contrast, the experimental class, which used Umia cards, achieved a mean N-gain score of 0.7106, placing it in the "High" category and indicating a significant improvement in student performance. This considerable enhancement over the control group underscores the superior effectiveness of the Umia cards intervention. The key differentiator between the two interventions lies in the comprehensive, interactive nature of the Umia cards. Unlike molymod, which primarily focuses on visualization, Umia cards integrate several interactive features, such as practice questions, learning videos accessible through QR codes, and immediate feedback mechanisms. These features support not only the visualization of molecular structures but also engage students in active learning. The learning videos provided through the cards offer in-depth explanations of how atoms combine to form molecules, addressing a crucial aspect that Molymod fails to cover in detail (Sausan et al., 2020; Putranta et al., 2021; Mihasan, 2021). This additional layer of explanation, combined with interactive elements, allows students to engage more deeply with the content, fostering a better understanding of complex chemistry concepts.

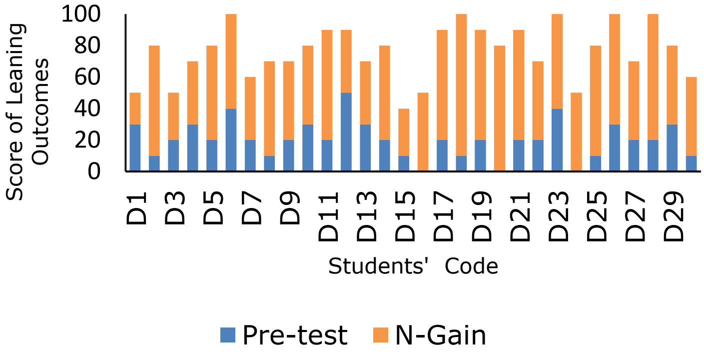

Figure 3. Students' learning outcomes of experimental group (N=30)

The effectiveness of Umia cards is further confirmed by the effect size measured using Cohen's d, which yielded a value of 1.259, indicating a high effect size. Based on Cohen's d table, this suggests that 88% of the control group would perform below the average student in the experimental group (Diani et al., 2016). This significant difference in performance highlights the dramatic impact of the Umia cards on student learning outcomes. The large effect size confirms that the use of Umia cards led to a substantial improvement in understanding and application of chemistry concepts compared to the moderate gains observed in the control group. This underscores the superiority of the Umia cards intervention and reinforces the argument that they are a more effective tool for enhancing learning.

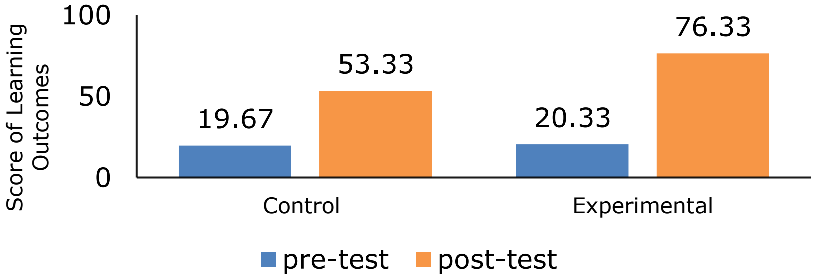

Figure 4. Comparison of average students' learning outcomes both of group

Several factors contribute to the success of the Umia cards. First, they encourage active participation and critical thinking. By interacting directly with the cards, students take ownership of their learning process, engaging in problem-solving, decision-making, and receiving feedback that enhances their ability to apply and master concepts (Mutayasiroh, 2021; Bacigalupo et al., 2024; Hardiansyah & Wahdian, 2023; Erlina et al., 2018). Furthermore, Umia cards promote a game-based learning approach, which not only makes learning more enjoyable but also stimulates students' motivation and creativity. Research has shown that game-based learning can significantly increase student engagement and motivation, contributing to a more effective and enjoyable learning experience (Yu et al., 2021; Deta et al., 2021).

The hands-on nature of the Umia cards allows students to physically manipulate the material, which leads to a better understanding of the concepts (Oh et al., 2023). This tactile interaction with the content helps bridge the gap between theoretical knowledge and practical application. The visual representations included in the cards make abstract concepts more tangible and easier for students to comprehend and retain (Vogt et al., 2020). Additionally, the Umia cards foster collaborative learning by encouraging students to work together to solve problems, share ideas, and learn from each other. This collaborative environment strengthens their understanding and enhances their overall learning experience (Chen et al., 2021). The versatility of the Umia cards, which can be used in both individual and group settings, ensures that they adapt to various classroom environments, maintaining student interest and promoting sustained engagement throughout the learning process (Sukerti & Pudjawan, 2020).

Table 11. The Effect Size Cohen's D test

Class	Paired Differences				t	N
	Mean	SD	95% Confidence Interval of the Difference			
			Lower	Upper		
Control	-33.66	16.50	-39.82	-27.50	-11.17	30
Experimental	-55.33	18.14	-62.10	-48.55	-16.70	30

Cohen's d = (55.501 - 33.667) / 17.341968

Cohen's d = 1.259027

The analysis results indicate a significant improvement in learning scores in the experimental group compared to the control group. The mean paired differences in the control group were -33.66 with a standard deviation of 16.50, whereas the experimental group showed a greater mean difference of -55.33 with a standard deviation of 18.14. The 95% confidence interval reveals that in the control group, the score differences ranged from -39.82 to -27.50, while in the experimental group, the range was broader, from -62.10 to -48.55.

This difference in mean scores reflects that the teaching methods applied in the experimental group had a more substantial impact on student learning outcomes compared to those used in the control group (Egara & Mosimege, 2024). Additionally, the higher standard deviation in the experimental group suggests variations in students' comprehension of the material (Egara & Mosimege, 2024). This indicates that while the use of innovative learning media generally enhances academic performance (Zakiyah et al., 2024), its effectiveness may vary among individuals depending on factors such as prior knowledge (Hattan et al., 2024), learning method (Safitri et al., 2024), and student engagement in the learning process (Ariani et al., 2024). Furthermore, the higher t-value in the experimental group (-16.70) compared to the control group (-11.17) suggests that the score changes before and after intervention were more significant in the experimental group. This finding indicates that technology-based learning media not only enhance students' understanding of the concepts taught but also have a more profound impact compared to conventional methods (Salamah et al., 2024).

The broader confidence interval in the experimental group compared to the control group reflects a wider distribution of learning outcomes among students. This suggests that while most students experienced significant improvement in comprehension, individual differences in the level of improvement were present (Ateş & Köroğlu, 2024). Factors such as cognitive abilities, visualization skills, and prior learning experiences may contribute to this disparity.

This study confirms that integrating interactive and visual media in chemistry education enhances students' understanding of abstract concepts, such as molecular geometry (Alharbi, 2025). Additionally, technology-based learning strategies not only improve academic performance but also boost students' motivation to grasp complex concepts (Bi et al., 2024; Mokmin et al., 2024). These findings emphasize the importance of incorporating innovative learning media to enhance student learning outcomes, particularly in comprehending abstract scientific concepts. Implementing technology-driven instructional strategies can effectively increase student engagement, foster deeper conceptual understanding, and accommodate diverse learning styles in an educational setting.

Conclusion

The result of this study confirm that Umia cards are highly effective in enhancing students' understanding of molecular shapes, significantly outperforming traditional Molymod models. The research successfully addresses gaps in instructional strategies by demonstrating that an interactive, game-based learning approach fosters deeper conceptual understanding, increased motivation, and improved academic performance. Integrated feedback mechanisms and comprehensive explanations further support student engagement, making learning more dynamic and effective. These findings provide strong evidence for the effectiveness of Umia cards in chemistry education, aligning with the study's objective to advance the integration of interactive media for teaching abstract scientific concepts. Implementing technology-based learning strategies can be an effective approach to increasing student engagement, facilitating deeper conceptual understanding, and accommodating diverse learning styles in an educational setting.

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References

Agung, D., Muhab, S., & Irwanto, I. 2024. Identifying students' misconceptions about chemical bonding using a four-tier diagnostic test. *Journal of Research in Education and Pedagogy*, 1(1):46-62. https://doi.org/10.70232/nky2hc92

Aisyah, S., Putera, D.B.R.A., & Hadi, W.P.H. 2022. Penerapan teknologi pembelajaran dalam permainan kartu Uno kimia unsur terhadap respon siswa di lingkungan Pondok Pesantren. *Unesa Journal of Chemical Education*, 11(2):30–135. https://doi.org/10.26740/ujced.v11n2.p130-135

Alharbi, A.A. 2025. Cognitive learning approach to enhance university students' visualization of molecular geometry in chemical compounds: A case study in Saudi Arabia. *Journal of Radiation Research and Applied Sciences,* 18(1):101283. https://ui.adsabs.harvard.edu/link_gateway/2025JRRAS..1801283A/doi:10.1016/j.jrras.2024.101283

Alvianita, C., Tanti, T., & Hariyadi, B. 2022. Construction and validation of evaluation instruments for science learning programs based on context, input, process, and product (CIPP) models. *Jurnal Penelitian Pendidikan IPA*, 8(3):1089-1095. https://doi.org/10.29303/jppipa.v8i3.1369

Antonio, R.P., 2022. Effectiveness of blended instructional approach in improving students' scientific learning outcomes: A meta-analysis. *Journal of Higher Education Theory and Practice*, 22(5):221-239. https://doi.org/10.33423/jhetp.v22i5.5217

Ariani, F., Kustati, M., Reflianto, R., Yanti, N., & Wandi, J.I. 2024. The effect of flipped digital classroom and student engagement on english writing skills. *Studies in English Language and Education*, 11(2):976-997. http://dx.doi.org/10.24815/siele.v11i2.35990

Ateş, H., & Köroğlu, M. 2024. Online collaborative tools for science education: Boosting learning outcomes, motivation, and engagement. *Journal of Computer Assisted Learning,* 40(3):1052-1067. https://psycnet.apa.org/doi/10.1111/jcal.12931

Bacigalupo, M., Bekh, O., Binasco, A., Israel, H., & Weikert, G.L. 2024. " Scaffold", a deck of cards to design competence-oriented learning experiences (No. JRC136622). *Joint Research Centre*. https://dx.doi.org/10.2760/057661

Bi, J., Izadpanah, S., Mohammadi, Z., & Rezaei, Y.M. 2024. Investigating the impact of technology-based education on academic motivation, academic perseverance, and academic self-efficacy in english language learning skills. *Education and Information Technologies*, 29(15):20523-20545.http://dx.doi.org/10.1007/s10639-024-12712

Chen,S.Y., Tsai,J.C., Liu,S.Y., & Chang,C.Y., 2021. The effect of a scientific board game on improving creative problem solving skills. *Thinking Skills and Creativity*, 41: 100921. https://doi.org/10.1016/j.tsc.2021.100921

Cohen, J. 1998. *Statistical Power Analysis for The Behavior science (2nd ed.)* Hillsdale, NJ: Lawrance Earlbaum Associations.

Curtis, M.J., Alexander, S.P.H., Cirino, G., George, C.H., Kendall, D.A., Insel, P.A., Izzo, A.A., Ji, Y., Panettieri, R.A., Patel, H.H., Sobey, C.G., Stanford, S.C., Stanley, P., Stefanska, B., Stephens, G.J., Teixeira, M.M., Vergnolle, N., & Ahluwalia, A. 2022.

Planning experiments: Updated guidance on experimental design and analysis and their reporting III. *British Journal of Pharmacology,* 179(15):3907–3913. https://doi.org/10.1111/bph.15868

Deta,U.A., Kurniawan, F.K., Lestari, N A., Yantidewi, M., Jauhariyah, M.N.R., & Prahani, B. K. 2021. Literature review on the use of educational physics games in improving learning outcomes. In *Journal of physics: Conference series*, 1805(1):012038. IOP Publishing. http://dx.doi.org/110.1088/1742-6596/1805/1/012038

Diani, R., Yuberti, Y., & Syafitri, S. 2016. Uji effect size model pembelajaran scramble dengan media video terhadap hasil belajar fisika peserta didik kelas X MAN 1 Pesisir Barat. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 5(2):265-275. http://dx.doi.org/10.24042/jpifalbiruni.v5i2.126

Doo, M.Y., & Zhu, M. 2024. A meta-analysis of effects of self-directed learning in online learning environments. *Journal of Computer Assisted Learning*, 40(1):1-20. https://doi.org/10.1111/jcal.12865

E.N., Huraño, N.J., Sodoso, E.R., Sumagang, M.G., Jumao-as, J.J., Canoy, J., & Sanchez, J.M. 2024. Android-based audio-visual comics in enhancing conceptual understanding and motivation of chemistry concepts. *Orbital: The Electronic Journal of Chemistry*, 16(2):125-135. https://doi.org/10.17807/orbital.v16i2.19953

Egara, F.O., & Mosimege, M. 2024. Effect of blended learning approach on secondary school learners' mathematics achievement and retention. *Education and Information Technologies*, 29(15):19863-19888. http://dx.doi.org/10.1007/s10639-024-12651

Egara, F.O., & Mosimege, M. 2024. Effect of flipped classroom learning approach on mathematics achievement and interest among secondary school students. *Education and Information Technologies,* 29(7):8131-8150. http://dx.doi.org/10.1007/s10639-023-12145-1

Erlina, Cane C., & Williams, D.P., 2018. Prediction! The VSEPR game: using cards and molecular model building to actively enhance students' understanding of molecular geometry. *Journal of Chemical Education,* 95(6):991-995. https://doi.org/10.1021/acs.jchemed.7b00687

Erlina., Williams, D.P., Cane, C., Ulfah, M., & Wafiq, A.F. 2024. Reconstructing perspectives: investigating how molecular geometry cards (MGCards) and molecular model building (MMB) disrupt students' alternative notions of molecular structure–a qualitative study. *Chemistry Education Research and Practice,* 25(4):1052-1070. https://doi.org/10.1039/D3RP00038A

Fiandini, M., Nandiyanto, A.B.D., Al Husaeni, D.F., Al Husaeni, D.N., & Mushiban, M. 2024. How to calculate statistics for significant difference test using SPSS: Understanding students comprehension on the concept of steam engines as power plant. *Indonesian Journal of Science and Technology*, 9(1):45-108. https://doi.org/10.17509/ijost.v9i1.64035

Fischer, F., Bauer, E., Seidel, T., Schmidmaier, R., Radkowitsch, A., Neuhaus, B. J., Hofer, S. I., Sommerhoff, D., Ufer, S., Kuhn, J., Küchemann, S., Sailer, M., Koenen, J., Gartmeier, M., Berberat, P., Frenzel, A., Heitzmann, N., Holzberger, D., Pfeffer, J., Lewalter, D., Niklas, F., Schmidt-Hertha, B., Gollwitzer, M., Vorholzer, A., Chernikova, O., Schons, C., Pickal, A. J., Bannert, M., Michaeli, T., Stadler, M. & Fischer, M. R. 2022. Representational scaffolding in digital simulations – learning professional practices in higher education. *Information and Learning Sciences,* 123(11/12):645-665. https://doi.org/10.1108/ILS-06-2022-0076

Fitriana, H., & Waswa, A.N. 2024. The influence of a realistic mathematics education approach on students' mathematical problem solving ability. *Interval: Indonesian Journal of Mathematical Education*, 2(1):29-35. https://doi.org/10.37251/ijome.v2i1.979

Fraser, M.W., Richman, J.M., Galinsky, M.J., & Day, S.H. 2009. Intervention research: Developing social programs. *Oxford university press*. https://doi.org/10.1093/oso/9780195325492.001.0001

Gouëdard, P., Pont, B., Hyttinen, S., & Huang, P. 2020. Curriculum reform: A literature review to support effective implementation. *OECD Education Working Papers 239, OECD Publishing.* http://dx.doi.org/10.1787/efe8a48c-en

Govindasamy, P., Cumming, T.M., & Abdullah, N. 2024. Validity and reliability of a needs analysis questionnaire for the development of a creativity module. *Journal of Research in Special Educational Needs*, 24(28):1-16 http://dx.doi.org/10.1111/1471-3802.12659

Hake. 1999. Analyzing charge Gain scores. America Educational Research Association's Division, *measurrement and research methodology*. https://web.physics.indiana.edu/sdi/AnalyzingChange-Gain.pdf

Hamalik, O . 1994. *Media pendidikan*. Bandung: Citra aditya bakti

Hardiansyah, F., & Wahdian, A. 2023. Improving science learning outcomes through the development of the magic card box learning media. *Al-Ishlah: Jurnal Pendidikan*, 15(1):823-833. http://dx.doi.org/10.35445/alishlah.v15i1.2711

Hattan, C., Alexander, P.A., & Lupo, S.M. 2024. Leveraging what students know to make sense of texts: What the research says about prior knowledge activation. *Review of Educational Research,* 94(1):73-111. https://doi.org/10.3102/00346543221148478

Hikmah, U.N., & Ahmadi, F. 2020. Development of learning video to boost grade iv students citizenship learning outcomes. *Elementary School Teacher*, 3(1):19-24. http://dx.doi.org/10.15294/est.v3i1.27913

Istiningrum, R.B., & Wiyantoko, B. 2017. Improvemnet of learning outcomes inorganic chemsitry through cooperative learning approach types student teamsachievement divisions with the help of molymod props. *Internasional Journal of Chemistry Education Research,* 1(1):13-23. https://doi.org/10.20885/ijcer.vol1.iss1.art3

Janna, N.M., & Herianto. 2021. *Konsep Uji Validitas dengan Menggunakan SPSS*.

Johnson, R.L., Penny, J.A., & Gordon, B. 2008. *Assessing performance: Designing, scoring, and validating performance tasks*. Guilford Press.

Kabbilawsh, P., Kumar, D.S., & Chithra, N.R. 2024. Assessment of temporal homogeneity of long-term rainfall time-series datasets by applying classical homogeneity tests. *Environment, Development and Sustainability*, *26*(7):16757-16801. http://dx.doi.org/10.1007/s10668-023-03310-0

Khatun, N. 2021. Applications of normality test in statistical analysis. *Open journal of statistics*, 11(01):113-122. http://dx.doi.org/10.4236/ojs.2021.111006

Kiernan, N.A., Manches, A., & Seery, M.K. 2024. Resources for reasoning of chemistry concepts: multimodal molecular geometry. *Chemistry Education Research and Practice*, 25(2):524-543. http://dx.doi.org/10.1039/D3RP00186E

Kumar, D., Jaipurkar, R., Shekhar, A., Sikri, G., & Srinivas, V. 2021. Item analysis of multiple choice questions: A quality assurance test for an assessment tool. *Medical Journal Armed Forces India*, 77(6):S85-S89. http://dx.doi.org/10.1016/j.mjafi.2020.11.007

Maciejewski, M.L. 2020. Quasi-experimental design. *Biostatistics & Epidemiology*, 4(1):1-10. http://dx.doi.org/10.1080/24709360.2018.1477468

Mauliandri, R., Maimunah, M., & Roza, Y. 2021. Kesesuaian alat evaluasi dengan indikator pencapaian kompetensi dan kompetensi dasar pada RPP matematika. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, 5(1):803-811. https://doi.org/10.31004/cendekia.v5i1.436

Mihasan, M. 2021. A beginner's guideline for low-cost 3D printing of macromolecules usable for teaching and demonstration. *Biochemistry and Molecular Biology Education*, 49(4):521-528. https://doi.org/10.1002/bmb.21493

Mokmin, N.A.M., Hanjun, S., Jing, C., & Qi, S. 2024. Impact of an AR-based learning approach on the learning achievement, motivation, and cognitive load of students on a design course*. Journal of Computers in Education*, 11(2):557-574. http://dx.doi.org/10.1007/s40692-023-00270-2

Mutayasiroh, S.K. 2021. Komparasi media audio-visual dan media kartu dalam pembelajaran bahasa arab. *An-Nuqthah*, 1(1):25-29. https://doi.org/10.62097/an-nuqthah.v1i1.592

Ningsih, o., desnita, d., gusnedi, g., & darvina, y. 2023. Validitas instrumen untuk mengukur kelayakan modul ajar fisika di SMAN 13 Padang berbasis kurikulum merdeka belajar. *Jurnal Pendidikan Tambusai*, 7(2):17879-17886. https://doi.org/10.31004/jptam.v7i2.9172

Oh, H., Hsi, S., Posner, N., Dixon, C., Smith, T., & Cheng, T. 2023. Making computing visible & tangible: A paper-based computing toolkit for codesigning inclusive computing education activities. *International Journal of Child-Computer Interaction*, 38:100602. https://doi.org/10.1016/j.ijcci.2023.100602

Okoye, K., & Hosseini, S. 2024. Analysis of Variance (ANOVA) in R: One-Way and Two-Way ANOVA. in *R Programming: Statistical Data Analysis in Research*, *Singaore: Springer Nature Singapore,* pp.187-209. http://dx.doi.org/10.1007/978-981-97-3385-9_9

Parekh, R. 2024. Comparison analysis of construction costs according to LEED and non-LEED certified educational buildings. *Available at SSRN 4924703*,11(8):b410-b417. http://dx.doi.org/10.1729/Journal.41004

Putranta, H., Kuswanto, H., Dwandaru, W.S.B., Setiyatna, H., Rani, S.A., & Purnama, A. Y. 2021. Simple modeling of crystal structure of carbon tetrachloride, diamond, and fullerene using molymods. *TEM Journal*, 10(2):883-891. http://dx.doi.org/10.18421/TEM102-50

Rahman, M.A., Hanna, J., Zein, B. El, & Badr, L.K. 2022. A nonrandomized pretest posttest study on the impact of an educational pain management program on nurses' knowledge and attitudes regarding pain in a middle eastern country. *Pain Management Nursing*, 23(3):324–329. https://doi.org/10.1016/j.pmn.2021.07.003

Rahman, Y.A., Yeni, F., Apriyanti, F., & Habibah, F.A.F. 2024. Measuring the effectiveness of process writing approach to improve EFL students' writing proficiency via normalized gain. *Scope: Journal of English Language Teaching*, 9(1):566-573. http://dx.doi.org/10.30998/scope.v9i1.24410

Rohmawati, A. 2015. Efektvitas pembelajaran. *Jurnal Pendidikan Usia Dini*, 9(1):15-32. https://doi.org/10.21009/JPUD.091

Rosa, N.M. 2015. Pengaruh sikap pada mata pelajaran kimia dan konsep diri terhadap prestasi belajar kimia. *Jurnal Formatif*, 2(3):218–226. http://dx.doi.org/10.30998/formatif.v2i3.104

Safitri, R., Wahyuri, A.S., & Ockta, Y. 2024. The impacts of the project-based learning and problem-based learning models with self-confidence on students' learning outcomes. *Indonesian Research Journal in Education*, 8(1):269-283. https://doi.org/10.22437/irje.v8i1.31480

Salamah, U., Naysilla, N., & Juliadi, E. 2024. Current social studies learning: technology-based learning media for character education. *Edutechnium Journal of Educational Technology*, 2(1):25-42. https://doi.org/10/71365/edujet.v2i1.44

Santos, A.V., Rupprecht, A.J., Ogawa, K., Schneider, P.W., Brown, A.M., Santos, H.C., & Simpson, S. 2024. Exploring student misconceptions in bonding and resonance: a computational chemistry exercise for general chemistry laboratory. *Journal of Chemical Education*, 101(10):4381-4389. http://dx.doi.org/10.1021/acs. jchemed. 4c00694

Sari, Y., Solehah, G.H., & Mashuri, M.T. 2018. Pengaruh penggunaan media permainan kartu Uno pada materi senyawa hidrokarbon terhadap hasil belajar siswa. *Jurnal Vidya Karya* , 33(1):35-41. https://dx.doi.org/10.20527/jvk.v33i1.5391

Sausan, I., Saputro, S., & Indriyanti, N.Y. 2020. A new chemistry multimedia: How can it help junior high school students create a good impression?. *International Journal of Instruction*, 13(4):457-476. http://dx.doi.org/10.29333/iji.2020.13429a

Schrepp, M. 2020. On the usage of cronbach's alpha to measure reliability of UX scales. *Journal of Usability Studies*, 15(4):247-258. https://uxpajournal.org/ cronbachs-alpha-reliability-ux-scales/

Siregar, A.D., & Harahap, L.K. 2020. Pengembangan E-modul berbasis project based learning terintegrasi media komputasi *hyperchem* pada materi bentuk molekul. *Jurnal Penelitian Pendidikan Sains*, 10(1):1925-1931. https://doi.org/10.26740/ jpps.v10n1.p1925-1931

Siregar, E.A. and Wiyarsi, A. 2024. Students' chemical representation ability: A study on molecule shapes. In *AIP Conference Proceedings*, *AIP Publishing*, 2622(1). http://dx.doi.org/10.1063/5.0133256

Subekti, N., Syaukani, A.A., Fatoni, M., Subroto, S., & Raihan, A.A.D.A. 2021. Exercise Speed, Agility and Quickness (SAQ) To Improve Physical Fitness. *Kinestetik : Jurnal Ilmiah Pendidikan Jasmani*, 5(1):95–101. https://doi.org/10.33369/ jk.v5i1.14359

Sugiyono, D. 2013. *Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D*. Bandung : Alfabeta.

Sukerti, N.K., & Pudjawan, K. 2020. The positive effect of scramble learning model assisted by picture cards on students' learning outcomes. *International Journal of Elementary Education*, 4(4):481-487. https://doi.org/10.23887/ijee.v4i4.27216

Susanto, A. 2013. *Teori belajar dan pembelajaran di sekolah dasar*. Jakarta: Kencana

Utaminingsih, E.S., Ramadhani, M.H., Puspita, M.A., Sumartiningsih, S., Apriantoro, M.S., & Ihsandi, A. 2024. Fostering superior characters: Development of innovative instruments for critical reasoning and independent character in the realm of science topic. *Jurnal Penelitian Pendidikan IPA*, 10(8):4650-5661. http://dx.doi.org/10. 29303/jppipa.v10i8.7053

Vogt, A., Klepsch, M., Baetge, I., & Seufert, T. 2020. Learning from multiple representations: Prior knowledge moderates the beneficial effects of signals and abstract graphics. *Frontiers in Psychology*, 11:601125. https://doi.org/10.3389/fpsyg.2020.601125

Wahab, A., Junaedi, & Azhar, M. 2021. Efektivitas pembelajaran statistika pendidikan menggunakan uji peningkatan N-gain di PGMI. *Jurnal Basicedu*, 5(2):1039–1045. https://doi.org/10.31004/basicedu.v5i2.845

Wibowo, H. 2005. *Konsep Dasar Kimia*. Universitas Negeri Yogyakarta.

Wijnia, L., Noordzij, G., Arends, L.R., Rikers, R.M., & Loyens, S.M. 2024. The effects of problem-based, project-based, and case-based learning on students' motivation: A meta-analysis. *Educational Psychology Review*, 36(29):1-38. https://doi.org/10.1007/s10648-024-09864-3

Wirasmika, I.G.A.M.A., Kanca, I.N., & Dartini, N.P.D.S. 2023. Minat peserta didik dalam mengikuti pembelajaran PJOK materi bola besar di SD No. 9 Jimbaran tahun pelajaran 2022/2023. *Jurnal Pendidikan Jasmani, Olahraga dan Kesehatan*, 11(2):61-73. https://doi.org/10.23887/jjp.v11i2

Yang, X., & Du, J. 2024. The effect of teacher self-efficacy, online pedagogical and content knowledge, and emotion regulation on teacher digital burnout: a mediation model. *BMC psychology,* 12(1):51-63. https://doi.org/10.1186/s40359-024-01540-z

Yovanie, F. 2024. Learning chemical bonds in terms of identifying difficulties, misconceptions, learning media, and learning models: A systematic literature review. *Jurnal Penelitian Pendidikan IPA*, 10(6):292-303. http://dx.doi.org/10.29303/jppipa.v10i6.6823

Yu, Z., Gao, M., & Wang, L. 2021. The effect of educational games on learning outcomes, student motivation, engagement and satisfaction. *Journal of Educational Computing Research*, 59(3):522-546. http://dx.doi.org/10.1177/07356331209 69214

Zakiyah, Z., Boonma, K., & Collado, R. 2024. Physics learning innovation: Song and animation-based media as a learning solution for mirrors and lenses for junior high school students. *Journal of Educational Technology and Learning Creativity,* 2(2):183-191. https://doi.org/10.37251/jetlc.v2i2.1062

Zeng, H., & Luo, J. 2024. Effectiveness of synchronous and asynchronous online learning: a meta-analysis. *Interactive Learning Environments*, 32(8):4297-4313. https://doi.org/10.1080/10494820.2023.2197953