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Swaying into Geometry: Digital Materials for Van Hiele-Aligned Geometric Reasoning and Learning Interest

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Abstract

This study aimed to produce digital teaching materials based on Van Hiele's geometry theory, oriented towards enhancing junior high school students' geometric reasoning ability and learning interest. The research addressed the gap in readily available and effective digital resources that specifically integrate Van Hiele's framework to foster these crucial learning outcomes. This was a development research study employing the Successive Approximation Model (SAM), comprising Preparation, Iterative Design, and Iterative Development phases. The research involving 62 students and a mathematics teacher. Data were analyzed using both quantitative (from questionnaires, observation sheets, and tests) and qualitative methods (from validation sheets). Findings indicate that the developed digital teaching materials, applying Van Hiele's geometry theory and supported by Microsoft Sway, are feasible for use in learning processes, demonstrating high validity from expert validators, confirmed practicality through teacher and student feedback, and proven effectiveness in improving both geometric reasoning ability and student learning interest in the experimental class compared to the control class. These materials are characterized by being interactive, multimedia-rich, easily accessible, flexible, and capable of providing feedback. This developed product is recommended as a valuable learning tool to facilitate independent student learning, with educators advised to adjust material alignment with curriculum coverage.

Keywords: *Digital Teaching Materials; Van Hiele's Geometry Theory; Geometric Reasoning; Student Learning Interest*

Introduction

Establishing connections between various learning environments, both inside and outside school, is crucial. The most intriguing new factor is the role of digital media, particularly in education and learning. The transformative power associated with advancements in information and communication technology (ICT) has generated increased interest in its social implications. Digital media demonstrates a significant impact in the social world, and it raises important questions about an individual's literacy and fluency in using and engaging with technology (Choudhury et al., 2023). Digital media can also serve as a learning tool, such as digital teaching materials.

A Systematic Literature Review conducted by Djono et al., (2024) concluded that digital teaching materials offer several advantages, including ease of implementation, low cost, high flexibility, and wide reach. Research by Aktayeva et al., (2022) also concluded that the use of software in mathematics education can enhance students' understanding and appreciation for the subject, as well as develop creative abilities through the use of digital technology. The integration of information and communication technology in mathematics education is considered a way to improve the quality of teaching and learning. Furthermore, this research also suggests incorporating technology in mathematics education as it can boost students' interest and foundational knowledge. The use of digital technology in education is believed to have a significant impact on the learning process; digital teaching materials are expected to be utilized for student evaluation. A Systematic Literature Review (SLR) conducted by Mossulin & Medeiros (2023) after analyzing 50 documents on fractal geometry concluded that there are significant opportunities to integrate Fractal Geometry into mathematics teaching, which can enhance student engagement. The research indicates that Fractal Geometry has the potential to increase student motivation and facilitate the understanding of mathematical concepts. This research also suggests involving the use of applications to deliver geometry material. The role of technology in learning can be applied to teaching materials, as the novelty in aspects of digital teaching materials can help to increase students' interest or attention (Choudhury et al., 2023). Muin's, (2023) research shows that the role of Microsoft Sway as digital teaching material can help teachers create interactive media. As digital-based media, Microsoft Sway can enhance the digital skills of both students and teachers. Microsoft Sway is a user-friendly platform released in August 2015, whose advantage is its ability to facilitate the creation of interactive and visually appealing presentations (Thi et al., 2024). Geometry material requires good shape representation; Microsoft Sway, which can provide good visual displays, can help explain geometry material.

Geometry is used for surveying, navigation, astronomy, and other practical work. Geometry is not only learned by reading textbooks and memorizing a set of formulas. Students must seek the reasons behind each step, not just how to do it. After students see how principles are applied to solved problems, they are then ready to develop those principles on additional related problems (Rich & Thomas, 2009). Pujiastuti & Haryadi (2024) explained in their research findings that geometry is considered difficult to understand due to its characteristics requiring high visual or imagination abilities and analytical skills to comprehend abstract objects. This is why geometry has a high chance of causing mathematical misconceptions. Geometry taught in schools is useful for improving logical thinking and making correct generalizations to better understand arithmetic, algebra, calculus, and so on. Geometric conceptual abilities must be mastered by students in depth. Thus, geometric reasoning ability is needed to understand geometry material.

Reasoning ability is also explained in the Decree of the Head of the Agency for Standards, Curriculum, and Assessment of Education (BSKAP) Number 09 of 2022 concerning Dimensions, Elements, and Sub-elements of the Pancasila Student Profile in the Merdeka Belajar Curriculum, stating that one dimension in the Pancasila student profile is the critical reasoning dimension. Students who reason critically are able to objectively process both qualitative and quantitative information, build connections between various pieces of information, analyze information, evaluate, and conclude it. The elements of critical reasoning are acquiring and processing information and ideas, analyzing and evaluating reasoning, reflecting on thinking and thought processes in decision-making (Kemendikbudristek, 2022). Geometric reasoning is a common task in mathematics education (Li, 2008, p.18). Mathematical thinking and reasoning skills, including making conjectures and developing strong deductive arguments, are crucial as they form the basis for developing new insights and encouraging further study (National Council of Teachers of Mathematics, 2000). Afriansyah, (2022) through his research explained that junior high school students have misconceptions about quadrilateral material, especially when answering problems. Plane figure material needs to be re-emphasized at the junior high school level before discussing congruence.

One theory that aids the understanding of geometry through its learning stages is Van Hiele's theory of geometric thought. Van Hiele's theory of levels of geometric thinking was developed by a pair of Dutch mathematicians Pierre M. Van Hiele and Dina Van Hiele-Geldof in the late 1950s. The Van

Hieles sought to explain why so many students faced difficulties with the cognitive processes involved in geometric thinking (Fouze & Amit, 2021). Van Hiele's Geometry Theory can be one solution to improve students' geometry learning outcomes. This theory explains the stages of students' geometric reasoning development. Van Hiele's theory explains that geometry learning occurs in five levels: visualization, analysis, informal deduction, formal deduction, and rigor. Van Hiele's geometry theory also supports student learning interest. Iterbeke et al., (2022) stated in their research that student learning interest refers to the curiosity and attention students have towards an academic topic, which can increase effort and productive learning behavior. Utilizing an understanding of the stages of students' geometric reasoning development in developing digital teaching materials has the potential to enhance both geometric reasoning ability and student learning interest.

Based on the background explained, the Microsoft Sway application allows for the creation of digital teaching materials for congruence topics. An appealing display can also increase student learning interest. Therefore, the researcher intends to develop digital teaching materials with a novelty in the form of applying Van Hiele's geometry theory assisted by Microsoft Sway media, with the orientation of these teaching materials being geometric reasoning ability and student learning interest.

Methods

The development model used in this development research was the Successive Approximation Model (SAM). The Successive Approximation Model (SAM) was an iterative effort to achieve closer proximity to perfection (Reiser & Dempsey, 2018, p.23). SAM was an effective process for the design and development of engaging learning events, whether consisting of e-learning, instructor-led training, or a blend. SAM was a process intended to support the design and development of engaging and interactive learning events that are effective (Allen, 2014) Robert A. Reiser and John V. Dempsey argued that there was a need to move beyond ADDIE to a more appropriate model for instructional design and development. Allen proposed the Successive Approximation Model (SAM) for instructional design and development (Reiser & Dempsey, 2018, p.13). The flow of the SAM development model in this study consisted of three phases. These three phases included the Preparation Phase, Iterative Design Phase, and Iterative Development Phase. These three phases had to be carried out sequentially to obtain maximum results. Each phase had its own steps and important considerations.

The preparation phase was a time to gather background information about a project, clarify conflicting information, note initial objectives, and so on. During this phase, the researchers determined the main aspects that helped set targets, identified specific problems, and ruled out options. After gathering various information, the process moved to Savvy Start, where the collected information and assumptions were reviewed. Savvy Start was a smart beginning in the form of a brainstorming event where researchers and teachers reviewed the collected background information and generated initial design ideas. Brainstorming began by jumping to solutions that might already be in mind. Initial ideas were poured out through opinions, sketching, and rapid prototyping. Targeted information gathering was much more efficient than broad information gathering (Reiser & Dempsey, 2018, p.44). The iterative design phase began after Savvy Start was completed. Savvy Start was expected to generate enough information to produce a project plan (Reiser & Dempsey, 2018, p.46-47). These subsequent design needs could actually be identified in the development phase when problems or opportunities were found (Allen, 2014, p.43). This phase consisted of product planning and additional design. Product planning involved a quantitative assessment of development details affecting completion time. Additional design was identical to the Savvy Start review prototype design and often occurred concurrently with product planning to maintain the Savvy Start.

The iterative development phase allowed teachers to evaluate and make corrections. Teachers could get a glimpse of the design before researchers engaged in time-consuming refinements (Reiser &

Dempsey, 2018, p. 48). This phase consisted of design proof, alpha design, beta design, and gold design. Design proof was a visual and functional demonstration of the proposed solution. Design proof had greater utility than design prototypes because it was built directly in Microsoft Sway. Design proof sought potential problems. Evaluating design proof was the best opportunity for researchers to check how the product functioned as a whole. Design proof combined sample content, including examples of all components, with the design. Text and media were polished and represented final quality (Reiser & Dempsey, 2018, pp.48-49). The alpha release was a complete version of the instructional application that would be validated against the approved design. Evaluation of the alpha release identified deviations from style guides, graphic errors, text changes, sequencing issues, missing content, lack of clarity, and functional problems. The researchers scheduled a second cycle called the validation cycle. Validation was part of the process leading to the second final product candidate, the beta release. Beta was a modified version of alpha that incorporated necessary changes that had been identified by reviewers during the alpha evaluation. At this point, errors should have only included minor typos or corrections in graphics. The construction of the gold release was the final stage in the iterative development phase. Digital teaching materials that reached this stage could be measured for their effectiveness in improving geometric reasoning ability and student learning interest.

The trial subjects of this study were junior high school students in grades VII and VIII at a school in Yogyakarta City. Sampling was conducted using a purposive sampling technique. The consideration used was that the school had at least 3 parallel classes. The data collection techniques used in this study consisted of tests and non-tests. Research data sources were obtained from students, teachers, and observers. The research instruments consisted of validity, practicality, and effectiveness instruments. Validity instruments in this study were validation questionnaires for material and media experts, validation questionnaires for material and media experts, and validation questionnaires for geometric reasoning ability tests and student learning interest instruments. Instruments used to assess practicality also had to go through a validation stage, such as validation of teacher and student practicality questionnaires, and observation sheets. Validation questionnaires were prepared to obtain assessments, suggestions, and comments from validators. Validators consisted of material and media expert validators. Consistency had to exist between the intended teaching material plan and the tested teaching material. If both consistencies existed, the teaching material was categorized as practical (Akker et al., 1999, p. 127). The practicality questionnaire was filled out by teachers and students. The observation sheet filled out by the observer contained learning steps. The effectiveness instruments of digital teaching materials were geometric reasoning ability tests and student learning interest questionnaires.

Data analysis techniques consisted of validity, practicality, and effectiveness analysis. Content validity was determined using expert agreement. This was because measuring instruments, for example in the form of tests or questionnaires, were proven valid if experts believed that the instruments measured mastery of abilities defined in the domain or also the psychological constructs measured (Heri Retnawati, 2016, p.18). Practicality data analysis by teachers and students aimed to measure the practicality of digital teaching materials. This study used scoring on the practicality questionnaire with a Likert scale that had a maximum scale of 5 and a minimum scale of 1. The maximum ideal score obtained was 75 and the minimum ideal score obtained was 15. Thus, based on the formula above, the following practical criteria were obtained.

Table 1. Digital Teaching Material Practicality Criteria

Achievement Value (Score)	Percentage (%)	Category
$60 \leq x \leq 75$	$75 \leq x \leq 100$	Practical
$45 \leq x < 60$	$50 \leq x < 75$	Less Practical
$30 \leq x < 45$	$25 \leq x < 50$	Not Practical
$15 \leq x < 30$	$0 \leq x < 25$	Very Not Practical

Based on the table above, the practicality of digital teaching materials by teachers and students was considered practical if the minimum score achievement met 75% of the total score. Factors influencing the practicality of digital teaching materials were that the implementation of learning utilizing digital teaching materials was carried out by more than 80%. The effectiveness of digital teaching materials was analyzed from the results of geometric reasoning ability tests and student learning interest questionnaires. The intervals for assessing geometric reasoning ability and learning interest can be seen in the following table.

Table 2. Categorization of Geometric Reasoning Ability and Learning Interest

Interval	Category	Description
$90 \leq x \leq 100$	very high	Had reached learning objectives
$80 \leq x < 90$	high	
$70 \leq x < 80$	medium	
$0 \leq x < 70$	low	Had not reached learning objectives

The student learning interest questionnaire scores were analyzed using a Likert scale with an interval of 1-5. The use of a Likert scale allowed variables to be measured by breaking them down into sub-variables, which were then further broken down to be measurable (Riduwan & Sunarto, 2017, p.21). The effectiveness of the digital teaching materials discussed in this study was seen from their achievement against the Minimum Completeness Criteria (KKM) and the comparison of achievement between the experimental and control classes. The experimental class received learning assisted by the developed digital teaching material product, while the control class received learning with conventional teaching materials. The researchers discussed with the teacher to determine the classes to be tested, where the selected classes were assumed to have equivalent abilities.

Before conducting hypothesis testing, normality and homogeneity tests were carried out. The normality test is a way to determine whether the data distribution in a sample can reasonably be considered to come from a particular population with a normal distribution (Budiwanto, 2017, p. 190). The normality tests performed in this study were multivariate and univariate normality tests. The multivariate normality test used was the Henze-Zikler test, and the univariate normality test in this study was the Anderson Darling test. The data tested included pretest and posttest data of geometric reasoning ability and student learning interest questionnaires. The variance homogeneity test was conducted to ensure that the pretest and posttest had homogeneous variances. Homogeneity testing is testing to determine whether the variances of two or more distributions are the same or not (Budiwanto, 2017, p.195). The multivariate homogeneity test used for this research data was Box's M test. The univariate homogeneity test in this study used the Levene test.

Hypothesis testing for the effectiveness of digital teaching materials was performed multivariately and univariately to determine the effect of the developed digital teaching materials on both classes, then tested with an independent test. Normality and homogeneity of multivariate and univariate data greatly affected the test used. The first hypothesis tested was the multivariate pretest mean vector test to determine whether the students' initial abilities were equivalent between the experimental and control classes. If the pretest data were multivariate normal and homogeneous, Hotelling's T^2 MANOVA test could be used, but if both multivariate pretest assumptions were not met, Pillai's Trace test could be used. The significance level used was 0.05. The next test was a completeness test conducted to prove whether the posttest scores for both geometric reasoning ability and learning interest data in the experimental and control classes had met the minimum mastery threshold.

The data were tested using an appropriate multivariate test that adhered to the multivariate assumptions of normality and homogeneity. Hotelling's T^2 One-Sample Test indicated whether the group means were equal to the minimum mastery threshold of 70. If the group means were equal to 70, students were considered to have an average that met the minimum mastery threshold. If the means were not equal to 70, further testing was required using univariate one-sample tests, such as the One-Sample T-Test for data with normal and univariate homogeneous distribution, or the Wilcoxon test if any assumptions were not met. After testing the completeness of each posttest data set, a multivariate test of the posttest mean vectors was performed using Hotelling's T2 or Pillai's Trace, depending on the normality and homogeneity assumptions of the posttest data. Subsequently, an independent test was conducted to observe better improvements between the experimental and control classes.

Results and Discussion

This research yielded a digital teaching material product that applied Van Hiele's geometric theory, assisted by Microsoft Sway media, and oriented towards students' geometric reasoning ability and learning interest. The first development phase was the preparation phase, which consisted of information gathering and savvy start. During this phase, the researchers identified the problems to be solved and discussed them with school officials, ranging from teachers to the vice principal for curriculum. Information was collected in a targeted manner for efficiency. The information gathered included: the school used the Merdeka curriculum; teachers had not previously used interactive digital teaching materials that could receive student answers or other digital learning media in class; congruence material required greater geometric reasoning ability; challenges in mathematics learning included students often joking in class and lacking focus during lessons; students' mobile phones were turned off and collected during lessons but could be used under teacher supervision; the research schedule was adjusted to school activities arranged by the vice principal for curriculum; and students enjoyed technology-involved learning. After obtaining extensive information, the process proceeded to the savvy start stage. The outcomes of the Savvy Start in this study included a rough prototype and a Savvy Start Summary Report.

The second development phase was iterative design. This phase comprised product planning and additional design. Product planning resulted in the content design of the prototype that had been approved during the savvy start, followed by review and planning for improvements. The researchers compiled the material to be included in the digital teaching material, specifically subject matter, example problems, and practice problems from various sources. The researchers prepared a plan for which applications would be embedded into Microsoft Sway. Activities in the additional design stage involved adding supplementary prototypes to the basic prototype obtained from the savvy start. Several additional prototypes acquired included a media prototype, a functional prototype, an integrated prototype, and a technical prototype.

The iterative development phase consisted of four stages: design proof, alpha, beta, and gold. The researchers worked on the combined prototype results from the iterative design phase during the design proof stage, which involved visual and functional demonstrations of the proposed solution within the Microsoft Sway application. The alpha design was the result of the researchers' evaluation of the design proof. Evaluation outcomes that led to the transformation of the design proof into the alpha design included changing the background to a smoother design for reader focus on the material, replacing fonts and customizing the design, and modifying the format of the material on relationships between angles. After evaluating the design and material into the alpha design, the researchers were ready to provide the product to material and media expert validators. The modification of the alpha, which incorporated the validators' identified feedback, constituted the beta stage. Revisions made to transform the alpha design into beta included adding practice problems to each sub-material of congruence, changing illustrations in the second sub-chapter, highlighting characteristics of congruence, correcting confusing sentences, correcting videos, enriching practice problems, and reorganizing the material arrangement. After revising the input from the validators and deeming the digital teaching material valid, it was ready for testing in a small class or limited trial. Testing in the limited class assessed the practicality of the digital teaching material. Practicality was observed from student and teacher questionnaires regarding the use of the digital teaching material. Afterward, it was revised again to proceed to the gold stage. The digital teaching material that reached the gold stage could be measured for its effectiveness in improving students' geometric reasoning ability and learning interest. The gold stage represented the evaluation results from the limited trial; some revisions from the limited trial included correcting typographical errors in practice problems and refining multiple-choice options.

Product trials in this study were conducted twice: a small-class trial (limited trial) and a large-class trial. The small-class trial involved one Grade VIII class that had already covered congruence material, while the large-class trial involved two classes representing the Grade VII population. The practicality of the digital teaching material was assessed from teacher and student practicality questionnaires, as well as observation sheets for the implementation of the limited trial. The following results were obtained.

Table 3. Result of Practicality Test

Criteria	**Questionnaire on Practicality**		**Observation Sheet for Learning Implementation**
	Teacher	**Student**	
Total Score	58	1.437	29
Average	58	57,44	29
Percentage (%)	77,33	76,59	96,66

The practicality questionnaires for both teachers and students showed good results, with percentages for both exceeding 75%, indicating that the digital teaching material was categorized as practical. The observation sheet for the implementation of the limited trial supported this categorization, with a percentage above 80%. It was concluded that the digital teaching material, which applied Van Hiele's geometric theory and utilized Microsoft Sway media, and was oriented towards students' geometric reasoning ability and learning interest, had proven practical.

The effectiveness test in this study was reviewed based on the results of the pretest and posttest of students' geometric reasoning ability on congruence material, and the results of student learning interest questionnaires before and after treatment. The analysis for this research consisted of prerequisite tests, including normality and homogeneity tests, and univariate and multivariate effectiveness hypothesis tests. Inferential analysis in this study utilized the R application for its completion. The results of the multivariate normality test for the experimental and control class data are presented in the following table.

Table 4. Results of Multivariate Normality Test

Kelas	**Data**	**P-Value**	**Conclusion**
Experimental	Pretes	0.2843	Normally Distributed
	Posttest	0.591	Normally Distributed
Control	Pretes	0.3557	Normally Distributed
	Posttest	0.1234	Normally Distributed

The results from the multivariate normality test table indicated that both the experimental and control classes had multivariate normally distributed data for both pretest and posttest, as their p-values were greater than 0.05. After completing the multivariate normality test, a univariate normality test was subsequently performed. The results of this analysis are shown in the following table.

Table 5. Results of Univariate Normality Test

Class	**Ability**	**Data**	**P-Value**	**Conclusion**
Experimental	Geometric Reasoning	Pretes	0,1658	Normally Distributed
		Posttest	0,1567	Normally Distributed
	Student Learning Interest	Pretes	0,6034	Normally Distributed
		Posttest	0,752	Normally Distributed
Kontrol	Geometric Reasoning	Pretes	0,5063	Normally Distributed
		Posttest	0,1236	Normally Distributed
	Student Learning Interest	Pretes	0,2078	Normally Distributed
		Posttest	0,4107	Normally Distributed

It was concluded that all univariate data were normally distributed. Subsequently, the second assumption test, multivariate and univariate homogeneity tests, was conducted. The results of the homogeneity test for the covariance matrices of pretest and posttest are presented in the table below.

Table 6. Results of Multivariate Homogeneity Test

Covariance Matrix	p-value	Conclusion
Pretest	0.00538	Not Homogeneous
Posttest	0.9901	Homogeneous

The results of the Box's M test for homogeneity of covariance matrices indicated that only the posttest covariance matrix was homogeneous. This finding influenced the choice of mean vector tests. Specifically, the pretest mean vector test utilized Pillai's Trace due to the unfulfilled assumption, whereas the posttest mean vector test was able to use Hotelling's T^2 as it met the multivariate normality and homogeneity assumptions. Subsequently, a univariate homogeneity test, assessing the homogeneity of variances using Levene's test, was conducted. The results of the data homogeneity test are presented in the following table.

Table 7. Results of Univariate Homogeneity Test

Ability	Data	P-Value	Kesimpulan
Geometric reasoning	Pretest	0.0009	Variances Not Homogeneous
	Posttest	0.9248	Variances Homogeneous
Student Learning Interest	Pretest	0,54	Variances Homogeneous
	Posttest	0,7646	Variances Homogeneous

All data exhibited homogeneous variances, except for the pretest data of geometric reasoning ability. The initial effectiveness hypothesis test involved analyzing the pretest mean vector to determine if all pretest data were equivalent. Since the pretest data used were not multivariately normally distributed, MANOVA Pillai's Trace was employed. The results of the MANOVA Pillai's Trace test on the mean vector are presented in the following table.

Table 8. Results of Pillai's Trace Test for Pretest Mean Vectors

Mean Vektor	Pillai's Trace	p-value
Pretes	0,1259	0,0829

The results from the Pillai's Trace test table indicated that the p-value was greater than the significance level of 0.05. This led to the conclusion that there was no significant difference in the pretest mean vectors. This finding suggested that the initial abilities of students in both the experimental and control classes were largely similar. Therefore, to assess the effectiveness of the digital teaching material, only the posttest for each ability needed to be examined. The subsequent test aimed to determine the achievement of learning from the posttest of each class, specifically to ascertain whether each posttest data point had statistically reached the KKM (Minimum Completeness Criteria) of 70, and if students' learning interest had reached the "medium" category. The posttest data, having met multivariate normality and homogeneity assumptions, supported the use of a Hotelling's T^2 one-sample test. The results of the Hotelling's T^2 one-sample test for the experimental and control classes are presented in the table below.

Table 9. Results of Hotelling T^2 one sample test on Posttest Data

Class	Hotelling T^2	F-statistic	p-value
Experimental	42,07	19,93	$2{,}73 \times 10^{-5}$
Control	31,97	15,14	0,000139

The posttest data of both classes showed very small p-values, below the significance level of 0.05. Thus, it was concluded that the posttest mean for each class was not equal to 70. Data not equal to 70 could be above or below 70. Multivariately, the posttest of both classes was not equal to 70, therefore the analysis continued to univariate, to determine whether statistically the data were above or below 70. The posttest data in this study met the univariate normality and homogeneity assumptions, therefore the one-sample test that could be performed was the one-sample T test. The results of this one-sample test can be seen in the following table.

Table 10. Result of One Sample T Test

Class	Data	T-value	T-Table	P-Value	Conclusion
Experimental	Posttest Geometric Reasoning	2,406	1,734	0.01325	Minimum completeness achieved
	Posttest Learning Interest	6,052		$4{,}02 \times 10^{-6}$	Minimum completeness achieved
Control	Posttest Geometric Reasoning	-5,170		1	Minimum completeness not achieved
	Posttest Learning Interest	2,058		0.02679	Minimum completeness achieved

The one-sample test results showed that the minimum completeness for the experimental class was achieved for both cognitive and affective abilities, but geometric reasoning ability was not achieved by the control class. The achievement of minimum completeness in the experimental class indicated that the developed digital teaching materials were able to help students surpass the minimum completeness in geometric reasoning and student learning interest. The next effectiveness test determined whether digital teaching materials were effective for both dependent variables. The test performed was the posttest mean vector test using Hotelling's T^2 because multivariate normality and homogeneity assumptions were met. The results of Hotelling's T^2 test on the posttest mean vector can be seen in the following table.

Table 11. Results of Hotelling T^2 Posttest Mean Vector Test

Mean Vektor	Test Statistic	p-value
Posttest	36,38	4.019e-06

The results of the Hotelling T^2 Posttest Mean Vector Test showed that the p-value was less than 0.05, so there was a significant difference in the posttest mean vector between the experimental and control classes. This indicated that the two groups were not equivalent after receiving treatment. The existing difference between the two groups indicated that a comparative test between the two groups was needed to see which treatment was better. The results of the independent T test were as follows.

Table 12. Results of Independent T Test

Variable	p-value
Geometric Reasoning	5.005e-06
Student Learning Interest	0.004816

The p-values for both variables were below the significance level of 0.05. This meant that the geometric reasoning ability and student learning interest in the experimental class showed a better increase than the control class.

Results and Discussion

This study produced digital teaching materials that applied Van Hiele's geometry theory, aided by Microsoft Sway media, and were oriented towards students' geometric reasoning ability and learning interest. The product resulting from this research could be accessed via the link https://sway.cloud.microsoft/OX7pBQ4tDiBGQlHH?ref=Link. The quality of these digital teaching materials was tested and obtained valid, practical, and effective results. The developed digital teaching materials had several characteristics that could be considered their advantages, including being interactive, multimedia-rich, easily accessible, flexible, and providing instant feedback. Student interactivity in the digital teaching materials could be seen from the two-way interaction when students worked on exercises and proved the angle relationships theory with GeoGebra. The multimedia aspect of the digital teaching materials could be seen from the various media in the form of images, videos, and applications that were collaborated to support learning. Accessing the teaching materials using a link made them accessible on any device. The flexibility of the digital teaching materials could be seen from Microsoft Sway's ease in its editing features, which could be adjusted without having to change the access link. Feedback in the digital teaching materials could be obtained instantly by students after completing practice questions.

Plomp & Nieveen (2013, p.160) divided validity into two parts: relevance and consistency. Relevance referred to the content validity of a product, while consistency referred to construct validity. If a development product met these two requirements, then the product was said to be valid. This study conducted content validity for each research instrument used and the developed product, while construct validity was performed on instruments used to measure the effectiveness of digital teaching materials on affective abilities, namely student learning interest. Content validity was determined by the results of validator analysis, and construct validity was analyzed by factor analysis. The validation results from material and media experts stated that the digital teaching materials were ready to be tested with several revisions to the material, practice questions, and interactive media in the digital teaching materials. After making revisions according to the validators' directions, the teaching materials were considered valid. Construct validity was performed on the student learning interest instrument after a limited trial was conducted. Construct validity was analyzed using factor analysis. Factor analysis showed that the indicators of learning interest were theoretically and empirically similar. Thus, it was proven that the digital teaching materials and various research instruments in this study met the validity tests required by Plomp & Nieveen (2013, p.160).

The practicality of the digital teaching materials was evaluated through the assessment process on the teacher practicality sheet, student practicality sheet, and the limited trial observation sheet for the use of digital teaching materials in learning. The teacher and student practicality sheets showed good results, with both percentages above 75%, indicating that the digital teaching materials were categorized as practical. The observation sheet for the implementation of the limited product trial showed that the percentage was above 80%. Through these three important aspects, it could be concluded that the tested digital teaching materials were practical.

The effectiveness of these developed digital teaching materials could be measured by their role in enhancing geometric reasoning ability and student learning interest. The effectiveness of digital teaching materials in improving geometric reasoning ability and student learning interest could be seen from the statistical tests that showed the effectiveness of the digital teaching materials. The equivalent pretest mean vector test showed that the improvement in student ability could be analyzed from their posttest. The multivariate and univariate one-sample tests statistically showed that experimental class students obtained scores above the KKM for both dependent variables, namely geometric reasoning ability and student learning interest. The posttest mean vector test showed that there was a difference between the posttest means; because there was a difference, an independent test needed to be conducted. The independent test showed that the experimental class, which used digital teaching materials, achieved a better increase in geometric reasoning ability and learning interest than the control class. Therefore, digital teaching materials were considered effective in enhancing geometric reasoning ability and student learning interest.

Conclusion

Based on the results of the development and research in the form of a digital teaching material product applying Van Hiele's geometry theory assisted by Microsoft Sway media, oriented towards geometric reasoning ability and student learning interest, it can be concluded that the digital teaching materials possess characteristics such as being interactive, multimedia-rich, easily accessible, flexible, and capable of providing feedback. The digital teaching materials and research instruments were valid based on the review of material and media expert validators. The digital teaching materials were practical, as per the practicality test results measured from teacher practicality questionnaires, student practicality questionnaires, and limited trial implementation observation sheets. The digital teaching materials were effective in enhancing geometric reasoning ability and student learning interest. Effectiveness was proven through the analysis of learning objective achievement measured by KKM and the better increase in the experimental class compared to the control class. The experimental class received learning with digital teaching materials, while the control class did not. The experimental class showed a more significant increase in both geometric reasoning ability and student learning interest.

References

Afriansyah, E. A. (2022). *Mosharafa: Jurnal Pendidikan Matematika Peran RME terhadap Miskonsepsi Siswa MTs pada Materi Bangun Datar Segi Empat*. *11*(3). http://journal.institutpendidikan.ac.id/index.php/mosharafa.

Akker, J. van den, Branch, R. M., Gustafson, K., Nieveen, N., & Plomp, T. (1999). Design Approaches and Tools in Education and Training. In *Design Approaches and Tools in Education and Training*. Springer Netherlands. https://doi.org/10.1007/978-94-011-4255-7.

Aktayeva, A., Zubareva, E., Dautov, A., Saginbayeva, K., Niyazova, R., Khan, S., & Shonasheva, A. (2022). Aesthetic education: The process of teaching mathematics with the open-source software. *Transportation Research Procedia*, *63*, 285–293. https://doi.org/10.1016/j.trpro.2022.06.015.

Allen, M. (2014). *Leaving ADDIE for SAM Field Guide Richard Sites and Angel Green Guidelines and Templates for Developing the Best Learning Experiences*. American Society for Training & Development (ASTD). www.copyright.com.

Budiwanto, S. (2017). *Metode Statistika Untuk Mengolah Data Keolahragaan*. Fakultas Ilmu Keolahragaan Universitas Negeri Malang.

Choudhury, A., Biswas, A., & Chakraborti, S. (2023). *Digital Learning based Education* (A. Choudhury, A. Biswas, & S. Chakraborti, Eds.). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-8967-4.

Djono, Sudiyanto, Sukmawati, F., & Salimi, M. (2024). Systematic literature review: effects of digital teaching materials on learning achievement. *International Journal of Evaluation and Research in Education*, *13*(4), 2678–2688. https://doi.org/10.11591/ijere.v13i4.26357.

Fouze, A. Q., & Amit, M. (2021). Teaching Geometry by Integrating Ethnomathematics of Bedouin Values. *Creative Education*, *12*(02), 402–421. https://doi.org/10.4236/ce.2021.122029.

Heri Retnawati. (2016). *Analisis Kuantitatif Instrumen Penelitian* (1st ed.). Parama Publishing. www.nuhamedika.gu.ma

Iterbeke, K., Schelfhout, W., & De Witte, K. (2022). The role of students' interests during computer-assisted learning: A field experiment. *Computers in Human Behavior*, *130*. https://doi.org/10.1016/j.chb.2021.107168.

Jan van den Akker, Brenda Bannan, Anthony E. Kelly, Nienke Nieveen, & Tjeerd Plomp. (2013). *Educational design research. Part A : an introduction*. Netherlands Institute for Curriculum Development (SLO).

Kemendikbudristek. (2022). *Keputusan Kepala Badan Standar, Kurikulum, Dan Asesmen Pendidikan Kementerian Pendidikan, Kebudayaan, Riset, Dan Teknologi Nomor 009/H/Kr/2022 Tentang Dimensi, Elemen, Dan Subelemen Profil Pelajar Pancasila Pada Kurikulum Merdeka*.

Mossulin, Â. V. L., & Medeiros, L. F. de. (2023). O ensino de Geometria Fractal na Educação Básica: uma revisão sistemática de literatura. *REMAT: Revista Eletrônica Da Matemática*, *9*(2), e2004. https://doi.org/10.35819/remat2023v9i2id6397 .

Muin, A. (2023). The Effectiveness of Microsoft Sway-Based Media on the Learning Outcome of Cultural Art Subject in the Elementary School. *Journal of Educational Science and Technology*, *9*. https://doi.org/10.26858/est.v9i1.368996.

National Council of Teachers of Mathematics. (2000). *Principles Standards and for School Mathematics*.

Pujiastuti, H., & Haryadi, R. (2024). The Effectiveness of Using Augmented Reality on the Geometry Thinking Ability of Junior High School Students. *Procedia Computer Science*, *234*, 1738–1745. https://doi.org/10.1016/j.procs.2024.03.180.

Reiser, R. A., & Dempsey, J. V. (2018). *Trends and Issues in Instructional Design and Technology*. Pearson Education.

Rich, B., & Thomas, C. (2009). *Geometry includes plane,analytic,and transformational geometries* (4th ed.). The McGraw-Hill Companies.

Riduwan, & Sunarto. (2017). *Pengantar statistika untuk penelitian : pendidikan sosial ekonomi komunikasi dan bisnis*. Alfabeta.

Thi, N., Hanh, M., Thi, C., & Hang, H. (2024). Student's and Teacher's Perspectives on Integrating Microsoft Sway Into A Blended Intercultural Communication Course At Hanoi University of Industry. *Journal of Language and Life*. https://www.researchgate.net/publication/381612470.