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The Effect of Digital Media and Visual-Spatial Intelligence on Geometry Learning Outcomes for Grade 4 Elementary Students

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ABSTRACT

E-books and G-Sites are increasingly commonly used in geometry learning in elementary schools; therefore, it is necessary to conduct more intensive research to ensure the effectiveness of this digital media in accordance with the characteristics of students. This study investigated the effect of these media on Grade 4 students who have different levels of visual-spatial intelligence on their understanding of the subject of geometry. The study employed a quasi-experimental method with a 2x2 factorial design, pretest-post-test. The research subjects were 62 students. This study showed that (1) G-Sites is significantly more effective than e-books in improving geometry learning; (2) students who have high visual-spatial intelligence have a better understanding of geometry than those who have low visual-spatial intelligence; and (3) there is an interaction between digital media and students' visual-spatial intelligence on the understanding of geometry. G-Sites are a significantly more effective medium for students with low visual-spatial intelligence. The conclusion is that the use of digital media for geometry material should consider students' visual-spatial intelligence. We suggest that the use of e-books should be combined with concrete media. Concrete media can facilitate the process of externalization from 2D representation to 3D understanding, thereby reducing the cognitive load experienced by low-visual-spatial students. It is necessary to conduct research by considering other characteristics of students.

Keywords
Digital Media
E-Book
Elementary Student
Geometry Material
G-Sites
Visual-Spatial Intelligence

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Introduction

Digitalization will continue to occur in human life in the 21st century era, and in the education sector, digitalization is clearly seen in the digitization of instructional materials [1], [2], [3]. The advancement of Information and Communication Technology, or ICT, is a strong driver for the emergence of various multimedia that are increasingly rich to display information in various forms such as text, video, audio, visuals, and manipulative objects. This multimedia is also increasingly interactive so that it can facilitate users to combine, manipulate, and control various forms of media, such as computer graphics, text, animations, audio materials, and video. This digital technology allows teaching materials to be developed according to the characteristics of the material, the characteristics of students, and interesting and interactive [1], [4]. Textbooks or printed materials are developed into digital books or electronic books (e-books) and Google Sites (G-Sites) with the use of website-based technology. Both e-books and G-sites [5], [6], [7] are instructional media and, at the same time, disseminators of digital content that are widely used.

Digital media is very interesting to be applied in the field of education because of its visualization capabilities, especially in geometry material in mathematics lessons. E-books and G-sites are increasingly used as instructional media, especially in the field of science and less in the field of humanities [6], [7], [8]. Both e-books and G-Sites in general have improved learning outcomes in various fields of study and education levels [5], [6]. Based on the level of education, the use of e-books is most widespread in higher education, which is 76.2%, while at the elementary school level, it is very small, which is 9.20% [5], but advances in ICT encourage the use of technology in geometry lessons in elementary schools [9], [10]. The latest research in geometry learning has led to immersive media such as augmented reality (AR), but this technology is still new and not easily accessible [11], [12] and costly; hence, e-books and G-sites are more implementable and accessible.

G-Sites has the advantage of displaying interactive multimedia content that can enhance the learning experience of students, while e-books provide systematic material, although they are less interactive compared to G-Sites. A meta-analysis concluded that e-books facilitate visualization, spatial understanding, and engagement, leading to improved

comprehension of geometric concepts, especially at the elementary level [3]. Some of the existing empirical evidence is still inconclusive to be able to improve learning outcomes [3], [7], [13]; therefore, the effectiveness of e-books and G-Sites needs to be tested more deeply to validate their effect on improving geometry learning outcomes in elementary students because these media are increasingly used in elementary school [13][14]. One of the questions that needs to be addressed is whether this digital media is effective for all students or whether this digital media is more effective for students with certain characteristics. So that the success of learning using this media is determined by the characteristics of certain students. This study also answers the suggestions of the bibliometric analysis in 1996-2016, where there is still a lack of research on digital media associated with student differences during learning with multimedia [15].

Geometry material is related to visualization and spatial concepts, so that, theoretically, the characteristics of students related to this material are students' visual-spatial intelligence. In this study, students' visual-spatial intelligence as a moderator variable is suspected to affect the effectiveness of digital media. The findings of this study are expected to provide specifications for the use of digital media based on student characteristics, in this case, students' visual-spatial intelligence.

A. The Effect of Digital Media on Geometry Learning for Elementary Students

Geometry material in school studies concepts related to shape and its relationship to 3D (3-dimensional) concepts in Euclidean or Pythagorean space [16], [17]. "Geometry comprises those branches of mathematics that exploit visual intuition (the most dominant of our senses) to remember theorems, understand proofs, inspire conjectures, perceive realities, and give global insight" (Zeeman, quoted from [18]). Geometry learning in schools is not only to introduce mathematical concepts, but more than this, aims to develop students' thinking skills, such as improving spatial thinking skills and improving students' experience in measuring length, surface, and volume [19]. The characteristics of geometry naturally require instructional media that have high visualization. Based on the instructional goal of geometry learning, a medium that has a special ability to present geometry material is needed [19], [20]. The geometry materials require visual and manipulative content that experts recommend using AR media [21] due to valid evidence showing increased engagement and improved geometry learning outcomes. However, AR media is classified as a new technology, is not easily accessible, and is costly. E-books and G-Sites teaching materials currently remain the most promising as a platform for developing geometry materials for elementary school.

E-books are effective in increasing learning motivation and attracting students' attention in learning basic mathematics, especially if they use cartoon characters [21] [22]. Both G-Sites

and e-books are multimedia; they offer unique features. While e-books offer systematic content but are less interactive than G-Sites, G-Sites offer the advantage of displaying interactive multimedia content that can improve students' learning experiences. Table 1 summarizes the findings from several studies regarding the use of e-books and G-Sites in mathematics for elementary students.

Table 1. Effectiveness of E-books and G-Sites in Mathematics for Elementary Students

Digital Media	Outcomes Improved	Evidence Strength	Student's characteristics
e-books	Math achievement, motivation, and critical thinking. spatial skills	- High (but needs broader validation) - Not specific to Geometry learning	No specific student's characteristic
G-Sites	Concept understanding, engagement, and spatial thinking	- Moderate-High (needs larger studies) - not specific to Geometry learning	No specific student's characteristic

Resources: [3] , [13], [14], [23], [24]

Table 1 clearly indicates the potential of e-books and G-Sites to improve Geometry learning; however, ongoing, rigorous, and some aspects related to geometry learning are essential to provide information that is important for their effective use in classrooms.

B. The Effect of Students' Visual-Spatial Intelligence on Geometry Learning

Geometry subjects have an important position in the field of mathematics study because they are related to thinking skills, intuition, and creativity [25], [26]. The success of using e-books and G-Sites in learning Geometry is also determined by the characteristics of students[27], [28], especially students' visual-spatial intelligence or ability, [14], [17], [29], [30]. According to the Cognitive Theory of Multimedia Learning (CTML), students' visual-spatial ability can affect the effectiveness of digital media (e-books and G-sites). The CTML theory explains that messages in instructional media are instructional materials consisting of words (e.g., printed text or spoken text) and graphics (e.g., illustrations, photos, animation, video, or immersive virtual reality) aimed at accelerating students' understanding [17]. This theoretical proposition directs that students with high visual-spatial intelligence will learn geometry material faster because of their excellent imagination and pattern recognition skills [30]. The effects of Google Sites and e-books on learning should be examined by considering students' individual characteristics, particularly visual–spatial intelligence. The findings of this study offer practical recommendations for selecting and implementing digital media that are better aligned with diverse student characteristics, thereby supporting more effective and inclusive learning experiences.

C. The Effect of Digital Media and Students' Visual-Spatial Intelligence on Geometry Learning

Instructional delivery strategies pay special attention to instructional media and are influenced by the characteristics of the subject's material [27]. Thus, the selection and determination of instructional media must be in accordance with the characteristics of the material of geometry. Geometry is related to shape, and its relationship to the concept of 3D in Pythagorean space, so that to understand this material is closely related to the visual-spatial abilities that students have. Visual-spatial abilities consist of spatial visualization skills and spatial orientation [31]. Visual-spatial intelligence is the ability to understand, rotate, and reverse solid *objects* with imagination [32], [33]. Another term used for visual-spatial is spatial thinking [23], which involves three related properties: (1) awareness of space itself; (2) spatial information representation; and (3) the reasoning involved in interpreting spatial information (National Research Council, 2006). The higher the level of visual-spatial ability a person is expected to have, the easier it will be for a student to learn geometry [34], [35]. This is important in understanding geometric materials that demand imagination and visualization of objects. Understanding mathematical concepts includes not only memorizing formulas but also the ability to associate, explain, and apply concepts in various situations (NCTM, 1989).

The effect of digital media on geometry learning, viewed in relation to students' visual–spatial intelligence, can be theoretically predicted using the CTML [34]. This theory explains how verbal and visual information are processed through dual channels, influencing cognitive load and meaning construction, as reflected in the patterns presented in Table 2 and Table 3.

Table 2. Google Sites as interactive media/web media related to visual-spatial intelligence from the CTML perspective

Concept of CTML	Its relation to G-Sites	Implications on Interaction Outcomes
Multimedia Principles	Allows the merging of text, images, videos, and interactive navigation.	Effective media, if applied with the principles of coherence (no excessive information/decorative elements) and segmentation (breaking down complex material).
Coherence Principle	High risk. If G-Sites is too dense, has a lot of links, or is visually decorative, this increases the Extrinsic Cognitive Load.	The interaction effect may indicate that low Visual-Spatial Intelligence students are severely disadvantaged by cluttered sites, while high students can filter out such clutter.
Modalitas Principles	Can present visuals and audio/video narration at the same time.	Able to make optimal use of CTML Dual Channels, has the potential to provide high learning outcomes, resulting in general
Format	as an Interactive/Web Media	G-Sites offers a highly flexible format and high multimedia potential.

Table 3. E-books as static media/text-images related to visual-spatial intelligence from the CTML perspective

Concept of CTML	Its relation to e-Book	Implications on Interaction Outcomes
Dual channels	Tends to be dominated by visual/text channels; difficulty integrating audio narration, except using the reading feature.	E-books may be less effective at encouraging active processing (integrating verbal and visual information) than interactive G-Sites.
Cognitive Load	Rely more on students' internal visual-spatial abilities to process charts, graphs, or diagrams.	Students with high Visual-Spatial Intelligence may excel in using e-books because they have an easier time forming spatial mental models of static visuals (significant Visual-Spatial Intelligence Key Effects).
Individual Difference Principle	The effect of the interaction can indicate that e-books become a less supportive medium for students of low Visual-Spatial Intelligence, as they have difficulty in processing and integrating static and dense spatial information.	
Format	As an Interactive/Web Media	G-Sites offers a highly flexible format and high multimedia potential.

The findings of this study provide empirical data to convince of the effectiveness of e-books and G-Sites in geometry learning by considering students' visual-spatial intelligence in Grade 4 students. The geometry material in the context of this study is the measurement of the area of the flat plane and the volume of the plane of space. The relationship between Digital Media Students' visual-spatial intelligence and achievement of geometry learning is illustrated in Fig. 1.

Theoretical Framework of Research

The variables in this study consist of three variables: digital media (e-books and G-Sites), students' visual-spatial abilities (High and Low), and geometry learning outcomes. The relationship among these variables, which served as the foundational theory for this research, is described in the illustration in Fig. 1.

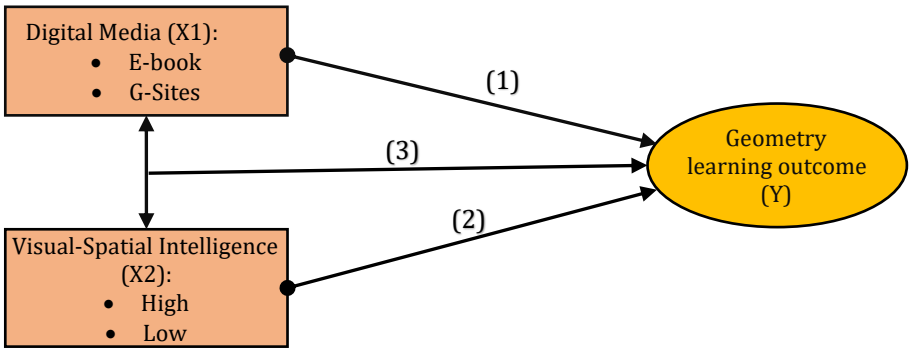


Fig. 1. Relationship between Research Variables

Based on Fig. 1, the problems solved from this study are

- Is there a difference in the learning outcomes of geometry among students who learn using G-Sites and E-Books in Grade 4?;
- Is there a difference in geometry learning outcomes among students who have high and low visual-spatial intelligence in Grade 4?; and
- Is there an effect of the use of digital media and students' spatial-visual intelligence on the learning outcomes of geometry in Grade 4?

Material and Methods

This study is quasi quasi-experiment with the pretest-posttest experimental research using a 2x2 factorial design. The three variables are the digital media, students' visual-spatial intelligence as an independent variable that functions as a moderator, and the dependent variable is the understanding of geometry (concept of area and volume). The research was conducted in semester 2nd of the 2024/2025 academic year from January to May 2024. The research subjects consisted of 62 Grade 4 students of SD Negeri Losari, based on existing classes, divided into Class 4A (using G-Sites) and Class 4B (using E-Book). The implementation of learning in grades 4 A and 4 B can be seen in Fig. 2.



(a) Class 4A learning with G-Sites



(b) Class 4B learning using an e-book

Fig. 2. Implementation of learning: (a) Class 4A learning using G-Sites; (b) Class 4B learning using e-Book

The research design uses a 2 x 2 factorial design, which is described in Table 4.

Table 4. Factorial design 2 x 2

		Digital Media	
		G-Sites	**e-Book**
Students' Visual-Spatial Intelligence	High	Group 1 (n=16)	Group 2 (n=12)
	Low	Group 3 (n=16)	Group 4 (n=18)

The Instruments used were: the visual-spatial intelligence test [35] and area and volume concept understanding test in the form of a multiple-choice test. The geometry learning outcome test is first tested for reliability before being given to students. The test results using the Cronbach's Alpha test were obtained with a value of 0.75, or reliable (See Table 5).

Table 5. Result of the Reliability Test

Cronbach's Alpha	N of Items
.745	21

Data analysis uses two-way ANOVA to determine the main influences and interactions between variables. The statistical requirements test consists of the Normality Test and the Homogeneity Test. The normality test techniques that can be used are such as the Kolmogorov-Smirnov test or the Shapiro-Wilk test; the results can be seen in Table 6.

Table 6. Result of Test of Normality

	Media	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	Df	Sig.
Score	G-sites	.203	32	.002	.935	32	.055
	e-Book	.209	30	.002	.938	30	.079

a. Lilliefors Significance Correction

Homogeneity tests were performed to see if the variances of the two groups (G-Sites and e-Books) were homogeneous. The Levene test was conducted for the homogeneity test (Table 7) as one of the preliminary requirements before conducting the ANOVA. The data exhibited an acceptable degree of homogeneity, $\alpha = 0.05$, in level of significance.

Table 7. Result of Homogeneity Test

Levene Statistic	df1	df2	Sig.
.015	1	60	.902

The two-way ANOVA was conducted to examine the effect of using Google Sites compared to e-books on students' understanding of geometric concepts, the effect of visual–spatial intelligence levels on geometry concept understanding, and the interaction between digital media use and visual–spatial intelligence in learning geometry.

Results and Discussions

This study aims to examine the effects of using Google Sites compared to e-books, as well as students' levels of visual–spatial intelligence, on fourth-grade elementary school students' understanding of geometry. To address these objectives, a two-way ANOVA was employed to analyze the main effects and their interaction. The results of this statistical

analysis are presented in Table 8, providing empirical evidence to support the interpretation of the findings.

Table 8. The results of the ANOVA test with SPSS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4150.135[a]	3	1383.378	68.624	.000
Intercept	346534.128	1	346534.128	17190.083	.000
Media	1974.311	1	1974.311	97.937	.000
Visual-Spatial Intelligence	2282.049	1	2282.049	113.203	.000
Media* Visual-Spatial Intelligence	178.468	1	178.468	8.853	.004
Error	1169.219	58	20.159		
Total	363887.500	62			
Corrected Total	5319.355	61			

a. R Squared = ,780 (Adjusted R Squared = ,769)

Table 8 shows the value of R Squared = 0.780 (Adjusted R Squared = 0.769). This value shows that the model involving media variables, Visual-Spatial Intelligence, and the interaction of the two is able to explain 78.0% of the variation in the geometry learning outcome score. This number is very high, indicating that the model is very good at predicting geometry learning outcomes. Furthermore, the results of the ANOVA analysis are discussed to answer the formulation of the research problem.

A. Significant Difference in the learning outcomes of geometry among students who learn using G-Sites and E-Books

The first research question in this study is, "Is there a difference in the learning outcomes of geometry among students who learn using G-Sites and e-books in Grade 4?" Table 8 shows that the F value sourced from the media is 97.937 (F (1, 58) = 97.937, Sig. = .000). This means that there is a significant difference in geometry learning outcomes in students who study with G-Sites and e-books. The results of the ANOVA analysis show that the geometry learning outcome of the use of G-Sites is higher than the use of e-books. This can be seen from the higher mean post-test scores of students in the group that used G-Sites. Another finding is that there is a significant influence of the instructional media used (G-Sites and E-Books) on students' geometry learning outcomes.

This supports the active learning process and improves the understanding of concepts in a more in-depth way compared to e-books that are less interactive and limited to text and static images. This is supported by the fact that the mean post-test score of students in the G-Sites class (80.161) is consistently higher than the e-Book class (71.333). The results confirm that interactive digital media enhances students' understanding and retention of geometry learning outcomes. Based on the Cognitive Theory of Multimedia Learning (CTML), G-Sites offers a more

interactive and engaging learning experience through integrated multimedia features directly [36].

B. Significant difference in geometry learning outcomes among students who have a high or low level of visual-spatial intelligence

The study also revealed that students with high visual-spatial intelligence gained better geometry learning outcomes than students with low visual-spatial intelligence, regardless of the media used. Table 8 shows that the F value sourced from the visual-spatial intelligence F (1, 58) = 113.203, Sig. = .000. Students with high visual-spatial intelligence show better post-test scores. Students with high visual-spatial intelligence have the ability to manipulate objects in their minds and understand the spatial relationships between parts. In the context of area and volume materials that rely on the visualization of geometric shapes, this ability is essential. Therefore, they are more likely to understand the concept of flat and space.

High levels of visual-spatial intelligence make it easier for students to understand geometric shapes, volumes, and size comparisons because they are able to imagine, rotate, and manipulate objects mentally [33], [37]. In the context of area and volume measurement, the ability to visually imagine the construction of spaces (e.g., cubes, blocks, tubes) is essential for students to be able to apply formulas correctly. Students with low visual-spatial intelligence tend to have difficulty performing spatial imagination, so they need concrete help (visual, manipulative, and interactive media). This is supported by students with high scores in visual-spatial tests, mostly scoring high in the post-test of concept comprehension, and students who fall into the low intelligence category mostly have difficulty in solving applicative and interpretive questions (C3 and C4 levels).

C. Interaction between Digital Media and visual-spatial intelligence on geometry learning outcomes

The results of the ANOVA test showed a significant interaction between the type of digital media and the level of visual-spatial intelligence. This means that the effectiveness of instructional media is greatly influenced by the level of visual-spatial intelligence of students. The results of the interaction test (interaction between media type and visual-spatial intelligence) showed a significant influence. This means that the effectiveness of instructional media depends on the level of visual-spatial intelligence of students. Students with high visual-spatial intelligence have the highest learning outcomes when using G-Sites because they offer powerful visual and spatial content such as animations, simulation videos, and interactive exercises. In contrast, students with low visual-spatial intelligence showed no significant improvement in either G-Sites or e-book use, although G-Sites scores remained slightly higher. This finding confirms that interactive digital media enhances students' understanding and retention of geometry concepts [38].

Students with high visual-spatial intelligence who use G-Sites have the highest scores compared to other groups (the most optimal combination). Students with low visual-spatial intelligence who use e-books have the lowest scores (the least optimal combination). Students with low visual-spatial intelligence who use G-Sites show better improvement than those who use e-books, but not as much as high visual-spatial students. From the perspective of the Cognitive Theory of Multimedia Learning [34], these findings can be described in Table 9.

The results of the ANOVA analysis in Table 8 found a significant interaction (p = 0.004). This means the effectiveness of G-Sites vs. e-books should be compared separately for the two categories of visual-spatial clarity (high and low). The Individual Differences Principle of CTML can provide a prediction of these findings, as outlined in Table 9.

Table 9. Prediction of research results on Visual-Spatial Intelligence based on the Individual Differences Principle of CTML Theory

Visual-Spatial Intelligence Level	CTML Prediction (Based on Cognitive Capacity)
High	Less susceptible to poor media design. Students with high visuospatial intelligence can organize information on their own. The difference in Postest score between G-Sites and E-books is predicted to be small/insignificant.
Low	Highly susceptible to Extrinsic Cognitive Load. Students with low visuospatial intelligence need media that is explicit, structured, and helps organize visuals. The difference in Postest score between G-Sites and E-books is predicted to be large/significant.

To determine which media actually provides a compensatory benefit, it is necessary to compare the average posttest values of each cell and (*p-value*, and the results are in Table 10.

Table 10. Post-test mean for four cells, as well as Significance comparison test results (p-value)

Cell/ Group	Visual-Spacial Intelligence	Digital Media	Mean Posttest ($\bar{X}$)	Comparison (Media vs Media)	p-value
1	High	G-Sites	83.13	G-Sites vs e-book (High Visual-Spatial Intelligence)	0.589
2	High	e-book	81.67		
3	Low	G-Sites	78.75	G-Sites vs e-book (Low Visual-Spatial Intelligence)	0.002
4	Low	e-book	68.89		

Based on the concept of CTML, it can be deduced:

- Post-test mean: G-Sites (83.13) is slightly higher than e-book (81.67), but the difference is not significant (p = 0.589). These results support the prediction of CTML, where students with high visual-spatial intelligence can learn effectively from both media.

Strong internal cognitive abilities enable students to overcome weaknesses in media design or format (Principle of Individual Difference).

- Post-test mean: there was a very significant difference in score (p = 0.002). The average post-test G-Sites score (78.75) is much higher than that of e-books (68.89). These results support CTML's predictions. Students with low visual-spatial intelligence rely heavily on the quality of media design. CTML explains as follows: (1) G-Sites function as effective compensatory support. This more interactive and structured media helps reduce extrinsic cognitive load, allowing low visual-spatial intelligence students to process information better and achieve a much higher post-test score; (2) G-Sites are a significantly more effective medium for students with low visual-spatial intelligence.

The Principle of Individual Difference from Multimedia Learning Cognitive Theory (CTML) proved to be valid in this study.

These findings imply that the use of these two forms of media must take into account the characteristics of students, such as students' visual-spatial intelligence. G-Sites, as a flexible web-based media, is well-suited for increasing student engagement in visual-spatial math learning, such as area and volume measurements. The development of instructional media needs to pay attention to interactive, visual, and responsive aspects in order to support students with multiple intelligences.

Suggestions can be made from research findings where geometry learning outcomes are low in the group of students who have low visual-spatial intelligence and learn with the use of e-books. When using e-books or other static digital teaching materials for geometry concepts in elementary school, they should be combined with the use of real or concrete (manipulative) media. Concrete media can facilitate the process *of externalization* from 2D representation to 3D understanding, thereby reducing the cognitive load experienced by low-visual-spatial students [1] [34] [39].

Conclusion

The results of this study are concluded as follows: (1) Students who learn using G-Sites get higher geometry learning outcomes than those who use e-books. (2) Students with high visual-spatial intelligence significantly show a higher geometry learning outcome. (3) There is an interaction between digital media and visual-spatial intelligence. G-Sites is more effective for students with low visual-spatial intelligence. The findings of this study imply that the use of G-Sites and e-books should consider the student’s visual-spatial intelligence. G-Sites, as a flexible web-based media, is well-suited for increasing student engagement in visual-spatial math learning, such as area and volume measurements. The development of instructional media needs to pay attention to interactive, visual, and responsive aspects in order to support students with multiple intelligences.

Conflict of Interest

The authors declare that there is no conflict of interest.

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